# The Electrochemical Society . . .

## 109th Meeting

**SAN FRANCISCO**
**April 29—May 3, 1956**

## LOCAL COMMITTEE

**Honorary Chairman**

R. L. Baldwin

**General Chairman**

R. F. Bechtold

**Arrangements**

Morris Feinleib

**Entertainment**

D. V. Doub

**Finance**

R. L. Zimmerly

**Plant Trips**

C. W. Tobias

**Publicity**

H. F. Myers

**Registration & Hotel**

J. F. Aicher

**Ladies' Entertainment**

Mrs. R. L. Baldwin, *Honorary Chairman*
S. L. Dreisbach, *Arrangements*

# THE ELECTROCHEMICAL SOCIETY

## One Hundred and Ninth Meeting

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**Sunday through Thursday**

**April 29, 30, May 1, 2, and 3, 1956**

### CONDENSED TECHNICAL PROGRAM

**Corrosion — Theoretical Electrochemistry (Abstracts 1–14)**

(All sessions in Bonanza Room, Mezzanine)

**Monday** morning, April 30—10:00 A.M.–12:15 P.M.

**Monday** afternoon, April 30—2:00 P.M.–5:00 P.M.

**Tuesday** morning, May 1—9:00 A.M.–12:00 M.

**Electric Insulation (Abstracts 15–25)**

**Monday** morning, April 30—10:00 A.M.–12:00 M.
(Argonaut Room, Mezzanine)

**Monday** afternoon, April 30—2:00 P.M.–5:00 P.M.
(Argonaut Room, Mezzanine)

**Tuesday** morning, May 1—9:30 A.M.–11:45 A.M.
(Argonaut Room, Mezzanine)

**Tuesday** afternoon, May 1—2:00 P.M.–5:00 P.M.—Paper and Round-Table Discussion
(Golden Empire and Bonanza Rooms, Mezzanine)

**Electronics — Luminescence (Abstracts 26–45)**

(All sessions in Argonaut Room, Mezzanine)

**Wednesday** morning, May 2—9:10 A.M.–12:00 M.

**Wednesday** afternoon, May 2—2:00 P.M.–4:30 P.M.
**Thursday** morning, May 3—9:00 A.M.–11:45 A.M.
**Thursday** afternoon, May 3—2:00 P.M.–3:00 P.M.

**Electronics — Semiconductors (Abstracts 46–60)**

(All sessions in Terrace Room, Fairmont Hotel)
**Wednesday** morning, May 2—9:00 A.M.–12:00 M.
**Wednesday** afternoon, May 2—2:00 P.M.–5:00 P.M.
**Thursday** morning, May 3—9:00 A.M.–12:00 M.
**Thursday** afternoon, May 3—2:00 P.M.–5:00 P.M.

**Electrothermics and Metallurgy—Arcs in Inert Atmospheres and Vacuum (Abstracts 61–75)**

(All sessions in Room of the Dons, Lobby)
**Monday** morning, April 30—10:00 A.M.–12:00 M.
**Monday** afternoon, April 30—2:15 P.M.–4:15 P.M.
**Tuesday** morning, May 1—9:00 A.M.–11:00 A.M.
**Tuesday** afternoon, May 1—2:00 P.M.–4:00 P.M.

**Electrothermics and Metallurgy—Marginal Ores (Abstracts 76–83)**

(All sessions in Golden Empire Room, Mezzanine)
**Monday** morning, April 30—10:00 A.M.–12:00 M.
**Monday** afternoon, April 30—2:15 P.M.–4:15 P.M.

**Electrothermics and Metallurgy—Pyrometallurgical Refining of Reactor Fuels (Abstracts 84–89)**

**Wednesday** morning, May 2—9:00 A.M.–12:00 M.

(Golden Empire and Bonanza Rooms, Mezzanine)

**Electrothermics and Metallurgy—Rare Earths (Abstracts 90–94)**

**Wednesday** afternoon, May 2—2:00 P.M.–4:30 P.M.
(Bonanza Room, Mezzanine)

**Electrothermics and Metallurgy—Recent Developments in Superrefractories (Abstracts 95–106)**

**Wednesday** afternoon, May 2—2:00 P.M.–4:00 P.M.
(Golden Empire Room, Mezzanine)
**Thursday** morning, May 3—9:30 A.M.–11:30 A.M.
(Golden Empire and Bonanza Rooms, Mezzanine)
**Thursday** afternoon, May 3—2:00 P.M.–4:00 P.M.
(Golden Empire and Bonanza Rooms, Mezzanine)

**Industrial Electrolytic (Abstracts 107–121)**

(All sessions in Terrace Room, Fairmont Hotel)
**Monday** afternoon, April 30—2:15 P.M.–4:45 P.M.
**Tuesday** morning, May 1—9:30 A.M.–11:30 A.M.
**Tuesday** afternoon, May 1—2:00 P.M.–4:30 P.M.

**Theoretical Electrochemistry (Abstracts 122–142)**

(All sessions in the Room of the Dons, Lobby)
**Wednesday** morning, May 2—9:00 A.M.–12:00 M.
**Wednesday** afternoon, May 2—2:00 P.M.–5:00 P.M.
**Thursday** morning, May 3—9:30 A.M.–11:30 A.M.
**Thursday** afternoon, May 3—2:00 P.M.–4:30 P.M.

## GENERAL INFORMATION

**Convention Headquarters** will be at the Hotel Mark Hopkins, California and Mason Streets, on Nob Hill, San Francisco, Calif.

Rates per day for rooms will be: single room: $10.00, 11.00, 12.00, 13.00, 14.00; double room: $14.00, 15.00, 16.00, 17.00, 18.00; suite: $25.00 to 40.00.

Requests for room reservations at the Headquarters Hotel should be made to the Reservation Department, Hotel Mark Hopkins, California and Mason Streets, San Francisco, Calif. Mention should be made of The Electrochemical Society.

Reservations for rooms have also been made at other hotels in San Francisco. Rates per day for rooms at these hotels will be:

Huntington, 1075 California St. (½ block from Mark Hopkins): single room $8.00–12.50; double room $8.00–15.00; twin-bed room $8.00–15.00; parlor suite $15.00–30.00.

Sir Francis Drake, 450 Powell St. (5 blocks from Mark Hopkins): single room $9.50–14.50; double room $11.50–16.50; twin-bed room $14.00–19.50; parlor suite $27.00–37.00.

Canterbury, 750 Sutter St. (5 blocks from Mark Hopkins): single room $6.00; double room $7.00; twin-bed room $10.00.

Chancellor, 433 Powell St. (5 blocks from Mark Hopkins): single room $5.75; double room $7.75; twin-bed room $8.75.

Requests for room reservations at these hotels should be made directly to the Reservation Department of the hotel concerned. Your name and address, a description of the accommodations desired, approximate arrival time, and date of departure should be given. Mention should be made of The Electrochemical Society.

The office of the Secretary will be in the Phoenix Room on the Mezzanine Floor, Hotel Mark Hopkins.

Technical sessions will be held on the Lobby Floor and Mezzanine Floor of the Hotel, as designated in the program.

Ladies' Headquarters will be in the Conquistador Room on the Mezzanine Floor throughout the meeting. Most of the ladies' activities will originate here. For details see the program under Ladies' Program.

## REGISTRATION

The registration desk will be located in the Lobby Writing Room in the Lobby of the Hotel. On Sunday, April 29, the registration desk will be open from 4:00 P.M. to 9:00 P.M. On Monday, Tuesday, and Wednesday, it will be open from 8:00 A.M. to 4:00 P.M.; on Thursday, from 8:00 A.M. to 12:00 M.

Registration fees are:

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|---|---|
| Members | $7.00 |
| Ladies | $3.00 |
| Students | $2.00 |
| Nonmembers | $10.00 |

## INFORMATION ABOUT SAN FRANCISCO

Since this is the first convention of The Electrochemical Society to be held in the West for many years, there will undoubtedly be a great interest in San Francisco, the San Francisco Bay Area, and the entire West Coast. The Society Convention Committee and the San Francisco Convention and Visitors Bureau are very anxious to assist, in any way they can, members and guests attending the convention to do any sightseeing, visiting, or vacationing they may desire. Booklets, pamphlets, and similar informative material will be available near the registration desk in the Lobby of the Hotel. However, it

would be wise to make any arrangements requiring reservations as much ahead of time as possible. Accommodations at the many national parks and resort areas near San Francisco are in great demand. For prior assistance in these matters, consult your local travel agent or write direct to the San Francisco Convention and Visitors Bureau, Civic Auditorium, San Francisco 2, Calif.

## ROUND-TABLE DISCUSSION AND SPECIAL SYMPOSIA

**The Electric Insulation Division** has scheduled a round table on "High Temperature Electrical Insulation, a New Frontier and a Challenge" at 3:00 P.M. on Tuesday, May 1, in the Golden Empire and Bonanza Rooms (Mezzanine).

**The Corrosion and Theoretical Electrochemistry Divisions** are sponsoring a symposium on "Adsorption Phenomena at Electrode Surfaces" all day Monday, April 30, and Tuesday morning, May 1, in the Bonanza Room (Mezzanine).

**The Electronics Division, Semiconductor Group,** has scheduled four symposia in the Terrace Room, Fairmont Hotel: (*a*) Elemental Semiconductors, on Wednesday, May 2, at 9:00 A.M.; (*b*) Semiconducting Alloys and Compounds, on Wednesday, May 2, at 2:00 P.M.; (*c*) Process Technology, on Thursday, May 3, at 9:00 A.M.; (*d*) Surface Controlled Phenomena, on Thursday, May 3, at 2:00 P.M.

**The Electrothermics and Metallurgy Division** has scheduled five symposia: (*a*) Arcs in Inert Atmospheres and Vacuums, all day Monday and Tuesday, April 30 and May 1, in the Room of the Dons (Lobby); (*b*) Marginal Ores and Their Relationship to the National Economy, all day Monday, April 30, in the Golden Empire Room

(Mezzanine); (*c*) Pyrometallurgical Refining of Reactor Fuels, on Wednesday morning, May 2, in the Golden Empire and Bonanza Rooms (Mezzanine); (*d*) Rare Earths, on Wednesday afternoon, May 2, in the Bonanza Room (Mezzanine); (*e*) Recent Developments in Super-refractories, on Wednesday afternoon, May 2, in the Golden Empire Room (Mezzanine) and all day Thursday, May 3, in the Golden Empire and Bonanza Rooms (Mezzanine).

**The Industrial Electrolytic Division** has scheduled two symposia in the Terrace Room, Fairmont Hotel: (*a*) Electrowinning and General, on Monday afternoon, April 30; (*b*) Fused Salt Electrolysis, all day Tuesday, May 1.

## BREAKFASTS, LUNCHEONS, AND DINNERS

### Symposia Chairmen Breakfasts

On Monday, Tuesday, Wednesday, and Thursday, April 30, May 1, 2, and 3, at 7:45 A.M., special breakfasts for all symposia chairmen are being arranged in the Peacock Lounge.

**Monday,** symposia chairmen for Corrosion—Theoretical Electrochemistry, Electric Insulation, Industrial Electrolytics, and Electrothermics and Metallurgy are requested to attend; **Tuesday,** Corrosion—Theoretical Electrochemistry, Electric Insulation, Industrial Electrolytics, and Electrothermics and Metallurgy; **Wednesday,** Theoretical Electrochemistry, Electronics, and Electrothermics and Metallurgy; **Thursday,** Theoretical Electrochemistry, Electronics, and Electrothermics and Metallurgy.

### Monday Luncheon and Annual Business Meeting

The Electrochemical Society Luncheon and Annual Business Meeting will be

held at 12:30 P.M. on April 30, in the Peacock Court (Lobby). An interesting speaker will be provided.

### Monday Evening Buffet Supper and Entertainment

Monday evening, April 30, has been reserved for an informal get-acquainted gathering. Cocktails, at 6:30 P.M., Room of the Dons (Lobby), will be followed by a buffet supper with floor show and entertainment in Peacock Court.

### Tuesday Evening Reception and Banquet

A reception for President and Mrs. H. H. Uhlig will be held at 6:30 P.M. in the Room of the Dons. Cocktails will be served followed by dinner in Peacock Court. President Uhlig will then deliver the Presidential Address. Dancing will follow.

## PLANT TRIPS

Two plant trips have been scheduled for this meeting. Participation in these trips must be arranged for at the time of registration for the convention. Transportation tickets can be obtained at the same time.

**Tuesday, May 1,** 10:00 A.M.—An inspection of Stanford Research Institute in Menlo Park has been arranged. SRI is the second largest organization of its kind in the U. S. Several of the divisions and research groups will be visited. Two types of groups will be organized: one spending the majority of its time in electronic engineering and one spending the majority of its time in the chemistry and physics laboratories. Transportation will be by chartered bus from the Hotel Mark Hopkins.

**Wednesday, May 2,** 5:30 P.M.—An inspection of the Radiation Laboratory, University of California, in Berkeley,

has been arranged. The tour will begin with a short orientation lecture. Five of the most interesting projects in the laboratory will then be visited. It will be possible to adapt the tours of the various groups to the particular interests represented in the group. Transportation will be by chartered bus from the Hotel Mark Hopkins ($1.25). Dinner will be served at the Faculty Club, University of California, at 6:30 P.M., at visitors' expense.

## LADIES' PROGRAM

Ladies' Headquarters will be in the Conquistador Room on the Mezzanine Floor of the Hotel Mark Hopkins throughout the meeting. All ladies are requested to visit this headquarters and register for the program which has been arranged. The various features of the program have been designed to allow sufficient time for shopping and other individual activities, attendance at the social functions of the general convention, and yet highlight some of the almost innumerable points of interest of San Francisco and the Bay Area.

**Monday, April 30**—After registration, coffee and doughnuts will be served in the Conquistador Room at 10:30 A.M. during a get-acquainted meeting and reviewing of the program. The Ladies' Committee will be present to answer any questions and help in any way. This will be followed by a Society Luncheon at 12:30, which the ladies are welcome to attend. At 2:00 P.M., a bus will leave from in front of the Mark to tour the city, returning around 5:00 P.M. A moderate charge of $3.35 per person will be made for this tour. In the evening, there will be the Buffet Supper and floor show, with cocktails at 6:30 P.M. and dinner at 7:30 P.M.

**Tuesday, May 1**—The ladies will have a Continental Breakfast at 9:15 A.M.

in the Mural Room of the St. Francis Hotel. Virginia Worth's tour of the most unique and interesting shops of San Francisco will follow. The afternoon will be free. In the evening, the ladies should plan to attend the Reception and Banquet for President and Mrs. Uhlig with cocktails at 6:30 and dinner about 7:30.

**Wednesday, May 2**—A bus will leave from the Hotel Mark Hopkins sharply at 10:00 A.M. to visit the Rod McLellan Orchid Nursery, traveling along the most scenic route. Around 12:30 P.M., lunch will be served at the Alta Mira (or Valhalla Inn) in Sausalito; arrival back at the Mark about 3:00 P.M. Evening free.

**Thursday, May 3**—The ladies will have coffee and doughnuts or rolls in the Conquistador Room at 9:30 A.M. The entire day is left free for individual plans. Members of the Ladies' Committee will be available to assist in any way they can.

## LUNCHEONS AND BUSINESS MEETINGS OF DIVISIONS

**Industrial Electrolytic Division** will hold a luncheon and business meeting on Tuesday, May 1, at 12:30 P.M. in the Nob Hill Room, Fairmont Hotel. W. C. Gardiner will give the Chlor-Alkali Committee Report.

**Electrothermics and Metallurgy Division** will hold a luncheon and business meeting on Wednesday, May 2, at 12:30 P.M. in the Nob Hill Room, Fairmont Hotel.

**Electronics Division** will hold a luncheon and business meeting on Thursday, May 3, at 12:30 P.M. in the Nob Hill Room, Fairmont Hotel,

**Theoretical Electrochemistry Division** will hold a business meeting on Thursday, May 3, at 11:30 A.M. in the Room of the Dons (Lobby), following the last Technical Paper on Thursday morning.

## BOARD AND COMMITTEE MEETINGS

**Sunday, April 29, 10:00 A.M.**—Meeting of the Ways and Means Committee in the Conquistador Room (Mezzanine).

**Sunday, April 29, 2:00 P.M.**—Meeting of the Board of Directors in the Conquistador Room (Mezzanine).

**Monday, April 30, 5:00 P.M.**—Meeting of the Council of Local Sections in the Conquistador Room (Mezzanine).

**Monday, April 30, 5:00 P.M.**—Meeting of the Editorial Staff in the Phoenix Room (Mezzanine).

**Tuesday, May 1, 5:00 P.M.**—Meeting of the Membership Committee in the Conquistador Room (Mezzanine).

**Wednesday, May 2, 5:00 P.M.**—Meeting of the Management and Editorial Committee of the Electronics Division in the Phoenix Room (Mezzanine).

**Wednesday, May 2, 5:00 P.M.**—Meeting of the Sustaining Membership Committee in the Conquistador Room (Mezzanine).

## COST OF VARIOUS FUNCTIONS

**(other than registration)**

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|---|---|
| Symposia Chairmen Breakfast | $2.00 |
| Division Luncheons | $3.75 |
| Monday Society Luncheon | $3.75 |
| Monday Cocktails, Buffet, and Entertainment | |
| (single) | $7.00 |
| (couple) | $11.00 |
| Tuesday Reception, Cocktails, Banquet, and Dancing | |
| (single) | $7.00 |
| (couple) | $11.00 |
| Meal Package [includes one divisional luncheon (lady's ticket not included), Monday Society Luncheon, Monday Buffet, and Tuesday Reception and Banquet] | |

(single)..... $19.35
(couple)..... $30.15
Plant Trip Transportation only (per person)
Radiation Laboratory..... $1.25
Stanford Research Institute... $1.25
Monday Ladies' Tour of San Francisco..... $3.35
*(Gratuities and taxes included in the above prices)*

## JOURNALS

Copies of the January, February, March, and April issues of the Journal of The Electrochemical Society will be available at the registration desk. The price of a single copy of the JOURNAL is $1.25 to members and $1.75 to nonmembers.

## EXTENDED ABSTRACTS

**The Electronics Division** again is making available an extended abstract booklet containing 1000-word abstracts of most of the papers presented at the Division's San Francisco symposia. Copies of the booklet will be on sale at the registration desk for $2.00.

**The Theoretical Electrochemistry Division** is also making available an extended abstract booklet containing 1000-word abstracts of most of the papers to be given at the Corrosion—Theoretical Electrochemistry symposia and the Theoretical Electrochemistry symposia at the San Francisco Meeting. Copies of the booklet will be on sale at the registration desk for $2.00.

## DISCUSSION

There will be no recordings made of oral discussions. Those contributing to the discussion of a paper and desiring their remarks published will be supplied by the symposium chairman with a printed form on which any discussion

may be written. These forms should be given to the Secretary-Treasurer of the Division or to the Managing Editor of the JOURNAL after the session. The discussion will then be referred to the authors for reply. Written discussion should be submitted within two months following publication of any article in the JOURNAL.

A discussion section is published semiannually in the JOURNAL.

## SLIDES AT TECHNICAL SESSIONS

The Board of Directors of the Society does not favor indiscriminate photographing of slides during technical sessions. It is requested that no such photographs be taken. Chairmen of technical sessions should administer this rule.

## EMPLOYMENT POSTERS

Companies which desire to recruit employees at the San Francisco Meeting will have posters to this effect on a bulletin board near the registration desk.

## MEETING ROOM SCHEDULES

| Meeting | Monday | | Tuesday | | Wednesday | | Thursday | |
|---|---|---|---|---|---|---|---|---|
| | A.M. | P.M. | A.M. | P.M. | A.M. | P.M. | A.M. | P.M. |
| Corrosion—Theoretical Electrochemistry | $D_2$ | $D_2$ | $D_2$ | | | | | |
| Electric Insulation | C | C | C | D | | | | |
| Electronics— | | | | | | | | |
| Luminescence | | | | | C | C | C | C |
| Semiconductors | | | | | A | A | A | A |
| Electrothermics and Metallurgy | | | | | | | | |
| Arcs in Inert Atmospheres | B | B | B | B | | | | |
| Marginal Ores | $D_1$ | $D_1$ | | | | | | |
| Pyrometallurgical Refining | | | | | D | | | |
| Rare Earths | | | | | | $D_2$ | | |
| Superrefractories | | | | | | $D_1$ | D | D |
| Industrial Electrolytic | | A | A | A | | | | |
| Theoretical Electrochemistry | | | | | B | B | B | B |

A = Terrace Room, Fairmont Hotel
B = Room of the Dons (Lobby).
C = Argonaut Room (Mezzanine).
D = Golden Empire and Bonanza Rooms (Mezzanine).
$D_1$ = Golden Empire Room (Mezzanine).
$D_2$ = Bonanza Room (Mezzanine).

# Technical Program

**Monday, April 30, 1956**

**9:00 A.M.**—Formal Opening of the 109th Convention with Introduction by General Chairman R. F. Bechtold and Response by President H. H. Uhlig (Room of the Dons, Lobby).

## CORROSION — THEORETICAL ELECTROCHEMISTRY

**Joint Symposium**

**Monday, April, 30 1956**

**Adsorption Phenomena at Electrode Surfaces**

**with Ernest Yeager presiding**

(BONANZA ROOM, Mezzanine)

**10:00 A.M.**—**"Survey of the Work on Polarization of Iron Electrodes in Acid Solutions"** (Invited paper) by K. F. Bonhoeffer, Max-Planck Institute for Physical Chemistry, Göttingen, Germany. (Abstract No. 1)

**10:45 A.M.**—**"Adsorption of Polyelectrolytes on a Mercury Surface"** (Invited paper) by D. C. Grahame and I. R. Miller, Dept. of Chemistry, Amherst College, Amherst, Mass. (Abstract No. 2)

**11:30 A.M.**—**"Adsorption and Corrosion"** (Invited paper) by Norman Hackerman, Dept. of Chemistry, University of Texas, Austin, Texas. (Abstract No. 3)

**12:30 P.M.**—Society Luncheon and Business Meeting in the Peacock Court (Lobby).

**Corrosion—Theoretical**

**Electrochemistry**

**Joint Symposium**

**Monday, April 30, 1956**

**Adsorption Phenomena at Electrode Surfaces** (cont'd)

**with Norman Hackerman presiding**

(BONANZA ROOM, Mezzanine)

**2:00 P.M.—"The Heat and Surface Potential of Adsorption of Hydrogen on Mercury"** (Invited paper) by J. O'M. Bockris and J. T. Law, John Harrison Lab. of Chemistry, University of Pennsylvania, Philadelphia, Pa. (Abstract No. 4)

**2:45 P.M.—"Hydrogen Evolution Kinetics and the Thermionic Work Function"** (Invited paper) by B. E. Conway and J. O'M. Bockris, John Harrison Lab. of Chemistry, University of Pennsylvania, Philadelphia, Pa. (Abstract No. 5)

**3:30 P.M.—"Adsorption and Polarography"** (Invited paper) by Paul Delahay, Dept. of Chemistry, Louisiana State University, Baton Rouge, La. (Abstract No. 6)

**4:00 P.M.—"Anodic Oxidation of Various Metals at Very Low Current Densities"** by H. Johansen, G. B. Adams, Jr., and Pierre Van Rysselberghe, Dept. of Chemistry, University of Oregon, Eugene, Oreg. (Abstract No. 7)

**4:30 P.M.—"Inhibition of Iron Corrosion in Acid Solutions"** by C. V. King and Eric Rau, Dept. of Chemistry, New York University, New York, N. Y. (Abstract No. 8)

**Corrosion—Theoretical**

**Electrochemistry**

**Joint Symposium**

**Tuesday, May 1, 1956**

**Adsorption Phenomena at Electrode Surfaces** (cont'd)

**with J. T. Waber presiding**

(BONANZA ROOM, Mezzanine)

**9:00 A.M.—"Electrical Double Layer Capacity and Surface Areas of Metals"** by Norman Hackerman and R. J. Brodd, Dept. of Chemistry, University of Texas, Austin, Texas.
(Abstract No. 9)

**9:30 A.M.—"Oxygen Overvoltage in Concentrated Acid Solutions, I. Perchloric Acid"** by T. R. Beck and R. W. Moulton, University of Washington, Seattle, Wash.
(Abstract No. 10)

**10:00 A.M.—"Inhibitory Processes at the Dropping Mercury Electrode, I. Structure of the Adsorbed Layer of Pyridine"** by L. Gierst and D. Bermane, Corrosion Lab., Massachusetts Institute of Technology, Cambridge, Mass. (Abstract No. 11)

**10:30 A.M.—"Inhibitory Processes at the Dropping Mercury Electrode, II. Inhibition of the Discharge of $PbO_2H^-$ by Pyridine"** by L. Gierst and D. Bermane, Corrosion Lab., Massachusetts Institute of Technology, Cambridge, Mass.
(Abstract No. 12)

**11:00 A.M.—"Radio-Tracer Technique for Continuous Measurements, in Situ, of Adsorption from Solutions"** by M. T. Simnad, Carnegie Institute of Technology, Schenley Park, Pittsburgh, Pa.
(Abstract No. 13)

**11:30 A.M.—"Kinetics of Silver-Silver Ion Exchange"** by C. V. King and Ann-Mari Simonsen, Dept. of Chemistry, New York University, New York, N. Y.
(Abstract No. 14)

## ELECTRIC INSULATION

**Monday, April 30, 1956**

**with D. A. Lupfer presiding**

(ARGONAUT ROOM, Mezzanine)

**10:00 A.M.—"Biological Insulating Materials"** by R. N. Hazelwood, Donner Lab. of Biophysics and Medical Physics, University of California, Berkeley, Calif. (Abstract No. 15)

**10:45 A.M.—"Dielectric Strength of Insulation Systems"** by D. A. Lupfer, Dielectric Materials, Electronics Div., General Electric Co., Syracuse, N. Y. (Abstract No. 16)

**11:20 A.M.—"Thermal Evaluation of Insulation"** by E. L. Brancato, U. S. Naval Research Lab., Washington, D. C. (Abstract No. 17)

**12:30 P.M.**—Society Luncheon and Business Meeting in Peacock Court (Lobby).

**Electric Insulation** (cont'd)

**Monday, April 30, 1956**

**with R. N. Hazelwood presiding**

(ARGONAUT ROOM, Mezzanine)

**2:00 P.M.—"Thermal Expansion of Filled Epoxy Resins"** by J. E. Carey, Rigid Plastics Technical Service, Shell Chemical Corp, Union, N. J. (Abstract No. 18)

**2:45 P.M.—"Electrical Properties of Epoxy Resins"** by C. H. Klute, Shell Development Co., Emeryville, Calif. (Abstract No. 19)

**3:30 P.M.—"Characteristics of Multilayer Dielectrics"** by D. A. Lupfer, Dielectric Materials, Electronics Div., General Electric Co., Syracuse, N. Y. (Abstract No. 20)

**4:15 P.M.—"Application of Insulators and Window Problems in Vacuum Tubes at Microwave Frequencies"**

by E. T. Jaynes, W. W. Hansen Labs. of Physics, Stanford University, Stanford, Calif. (Abstract No. 21)

**Electric Insulation** (cont'd)

**Tuesday, May 1, 1956**

**with E. L. Brancato presiding**

(ARGONAUT ROOM, Mezzanine)

**9:30 A.M.—"Effect of Voltage at Elevated Temperatures on Insulation Resistance of Ceramic Capacitors"** by K. H. Brandt, Convair Div., General Dynamics Corp., San Diego, Calif. (Abstract No. 22)

**10:15 A.M.—"Microstructure of Barium Titanates Ceramics"** by I. E. Burkes and R. C. de Vries, Research Lab., General Electric Co., Schenectady, N. Y. (Abstract No. 23)

**11:00 A.M.—"Phase Equilibria and Solid-State Reactions in the System of Talc-Clay"** by J. A. Pask, Div. of Mineral Technology, University of California, Berkeley, Calif. (Abstract No. 24)

(Late papers to be announced at meeting.)

**Electric Insulation** (cont'd)

**Tuesday, May 1, 1956**

**with Hans Thurnauer presiding**

(GOLDEN EMPIRE AND BONANZA ROOMS Mezzanine)

**2:00 P.M.—"Electrochemical Etching of High Purity Aluminum Capacitor Foil in Sodium Chloride Solutions"** by G. H. Kissin and Gloria S. Murphy, Dept. of Metallurgical Research, Kaiser Aluminum & Chemical Corp., Spokane, Wash. (Abstract No. 25)

**Round-Table Discussion**

**3:00 P.M.**—Round-table discussion on **High Temperature Electrical Insulation, A New Frontier and a Challenge,** with Hans Thurnauer leading the discussion.

## ELECTRONICS—LUMINESCENCE

**Wednesday, May 2, 1956**

**with J. H. Schulman presiding**

(ARGONAUT ROOM, Mezzanine)

**9:10 A.M.—Keynote Address—"Potentialities and Difficulties in the Interpretation of the Kinetics of Luminescence"** by M. Schön, Munich, Germany.

(Abstract No. 26)

**10:00 A.M.—"Radiation Resulting from the Recombination of Holes and Electrons in Silicon"** by J. R. Haynes, Bell Telephone Labs., Inc., Murray Hill, N. J.

(Abstract No. 27)

**10:30 A.M.—"Physical Basis of a Multiphonon Process"** by J. J. Markham, Zenith Radio Corp., Chicago, Ill. (Abstract No. 28)

**11:00 A.M.—"Thermoluminescence of Manganese-Activated Calcium Fluoride"** by R. J. Ginther and R. D. Kirk, U. S. Naval Research Lab., Washington, D. C.

(Abstract No. 29)

**11:20 A.M.—"Thermoluminescence of Titanium-Activated Lithium Silicates"** by P. J. Pizzolato, U. S. Naval Research Lab., Washington, D. C.

(Abstract No. 30)

**Electronics—Luminescence** (cont'd)

**Wednesday, May 2, 1956**

**with J. H. Schulman presiding**

(ARGONAUT ROOM, Mezzanine)

**2:00 P.M.—"Preparation of the Selenides of Hydrogen and Zinc"** by G. E. Crosby, Radio Corp. of America, Lancaster, Pa. (Abstract No. 31)

**2:20 P.M.—"Preparation of the Copper-Activated Zinc Selenide Phosphor by the Dry Process"** by G. E. Crosby, Radio Corp. of America, Lancaster, Pa. (Abstract No. 32)

**2:40 P.M.—"Ultraviolet Fluorescence of Some Ternary Silicates Activated with Lead"** by H. A. Klasens, A. H. Hoekstra, and A. P. M. Cox, Philips Research Lab., Eindhoven, Netherlands. (Abstract No. 33)

**3:10 P.M.—"Alkali Compensated Silicate Phosphor"** by G. E. Crosby, Radio Corp. of America, Lancaster, Pa. (Abstract No. 34)

**3:30 P.M.—"An Automatic Recording Radiometer"** by A. E. Martin, C. E. Meinheit, and F. W. Harjes, Sylvania Electric Products Inc., Bayside, N. Y. (Abstract No. 35)

**3:45 P.M.—"Some Practical Aspects of Electrophoretic Deposition"** by G. F. Kinney, Dept. of Chemical Engineering, U. S. Naval Postgraduate School, Monterey, Calif., and J. V. Festa, Microwave Tube Lab., Sylvania Electric Products Inc., Mountain View, Calif. (Abstract No. 36)

**4:00 P.M.—"Influence of Convection and Other Factors in Fluorescent Screen Uniformity"** by P. R. Myers, Lehigh University, Bethlehem, Pa., and C. T. Lattimer, RCA Victor Div., Radio Corp. of America, Marion, Ind. (Abstract No. 37)

**Electronics—Luminescence** (cont'd)

**Thursday, May 3, 1956**

**with J. H. Schulman presiding**

(ARGONAUT ROOM, Mezzanine)

**9:00 A.M.—"Time Average Electroluminescence Output of Some Zinc**

**Sulfide Phosphors"** by Sol Nudelman, U. S. Naval Ordnance Lab., White Oak, Md., and University of Maryland, College Park, Md., and Frank Matossi, U. S. Naval Ordnance Lab., White Oak, Md.

(Abstract No. 38)

**9:20 A.M.—"Electroluminescence of Zinc Sulfo-Selenide Phosphors with Copper Activators and Halide Coactivators"** by I. J. Hegyi, S. Larach, and R. E. Shrader, RCA Labs., Radio Corp. of America, Princeton, N. J. (Abstract No. 39)

**9:45 A.M.—"Physicochemical Aspects of Electroluminescence of Zinc Sulfide Phosphors with Copper Activator"** by S. Larach, R. E. Shrader, and I. J. Hegyi, RCA Labs., Radio Corp. of America, Princeton, N. J. (Abstract No. 40)

**10:00 A.M.—"Further Experiments on Electroluminescence of ZnS Single Crystals"** by D. R. Frankl, Physics Lab., Sylvania Electric Products Inc., Bayside, N. Y.

(Abstract No. 41)

**10:40 A.M.—"A Theory of the Electroluminescence of ZnS Single Crystals"** by J. L. Birman, Physics Lab., Sylvania Electric Products Inc., Bayside, N. Y. (Abstract No. 42)

**11:10 A.M.—"Some Experiments on Persistent Polarization and Photoconductivity in ZnS Crystals"** by A. Lempicki, Physics Lab., Sylvania Electric Products Inc., Bayside, N. Y.

(Abstract No. 43)

**12:30 P.M.**—Electronics Division Luncheon and Business Meeting in the Nob Hill Room, Fairmont Hotel.

**Electronics—Luminescence** (cont'd)

**Thursday, May 3, 1956**

**with J. H. Schulman presiding**

(ARGONAUT ROOM, Mezzanine)

**2:00 P.M.—"Incorporation of Chloride in ZnS Phosphor Preparation"** by A. Kremheller, A. K. Levine, and D. J. Bracco, Sylvania Electric Products Inc., Flushing, N. Y. (Abstract No. 44)

**2:30 P.M.—"The Release of Chloride from Zinc Sulfide by Grinding"** by A. Kremheller and A. K. Levine, Sylvania Electric Products Inc., Flushing, N. Y. (Abstract No. 45)

## ELECTRONICS—SEMICONDUCTORS

**Wednesday, May 2, 1956**

**Elemental Semiconductors**

**with G. K. Teal presiding**

(TERRACE ROOM, FAIRMONT HOTEL)

**9:00 A.M.—Introductory Remarks** by J. W. Faust, Jr.

**9:10 A.M.—Keynote Address—"Surface States on Semiconductors"** by J. Bardeen, University of Illinois, Urbana, Ill. (Abstract No. 46)

**9:40 A.M.—"Elemental Semiconductors"** by H. Y. Fan, Purdue University, Lafayette, Ind. (Abstract No. 47)

**10:10 A.M.—"Defects in Crystals of Silicon and Germanium Grown from the Melt"** by E. Billig, Associated Electrical Industries, Aldermaston, England. (Abstract No. 48)

**10:40 A.M.—"Rectifying Semiconductor Contacts—A Review of Theoretical Progress"** by H. K. Henisch, Sylvania Electric Products Inc., Bayside, N. Y., and Reading Univ., England. (Abstract No. 49)

**11:20 A.M.—"Distribution of Copper between Germanium and Ternary Melts Saturated with Germanium"** by C. D. Thurmond and R. A. Logan, Bell Telephone Labs., Inc., Murray Hill, N. J. (Abstract No. 50)

**Electronics—Semiconductors** (cont'd)

**Wednesday, May 2, 1956**

**Semiconducting Alloys and Compounds**

**with A. Beer presiding**

(TERRACE ROOM, FAIRMONT HOTEL)

**2:00 P.M.—"Conductivity and Band Gap Measurements of Some Relatives of Phthalocyanine"** by Wolfgang Felmayer and Irving Wolf, General Electric Co., Syracuse, N. Y. (Abstract No. 51)

**2:30 P.M.—"Ternary Compound Semiconductors with the Chalcopyrite Structure"** by I. G. Austin, C. H. L. Goodman, and A. E. S. Pengelly, The General Electric Co., Ltd., Wembley, England. (Abstract No. 52)

**2:45 P.M.—"Electronic and Ionic Fluctuation Processes in Semiconductors"** by R. E. Burgess, Dept. of Physics, University of British Columbia, Vancouver, B.C., Canada. (Abstract No. 53)

**3:15 P.M.—"Influence of the Absorption Edges of Cadmium and Silver on the X-Ray Diffraction Pattern of Cadmium Compounds"** by R. J. Robinson and F. Schossberger, Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill. (Abstract No. 54)

**3:45 P.M.—"Recent News" Papers.** Titles and short abstracts will be available at the registration desk.

**Electronics—Semiconductors** (cont'd)

**Thursday, May 3, 1956**

**Process Technology**

**with H. Q. North presiding**

(TERRACE ROOM, FAIRMONT HOTEL)

**9:00 A.M.—"The Status of Semiconductor Technology"** by F. J. Biondi,

Bell Telephone Labs., Inc., Murray Hill, N. J. (Abstract No. 55)

**9:30 A.M.—"A Metal-Semiconductor Capacitor"** by R. L. Taylor and H. E. Haring, Bell Telephone Laboratories, Inc., Murray Hill, N. J. (Abstract No. 56)

**10:00 A.M.—"Design of Diffused Junction Silicon Diodes"** by H. S. Veloric and K. D. Smith, Bell Telephone Labs., Inc., Murray Hill, N. J. (Abstract No. 57)

**10:30 A.M.—"Recent News" Papers.** Titles and short abstracts will be available at the registration desk.

**12:30 P.M.**—Electronics Division Luncheon and Business Meeting in the Nob Hill Room, Fairmont Hotel.

**Electronics—Semiconductors** (cont'd)

**Thursday, May 3, 1956**

**Surface Controlled Phenomena**

**with A. E. Middleton presiding**

(TERRACE ROOM, FAIRMONT HOTEL)

**2:00 P.M.—"Some Applications of Field Effect Studies on Germanium Surfaces"** by E. N. Clarke, Physics Lab., Sylvania Electric Products Inc., Bayside, N. Y. (Abstract No. 58)

**2:30 P.M.—"Anodic Oxidation of Silicon"** by P. F. Schmidt, Philco Corp., Philadelphia, Pa. (Abstract No. 59)

**3:00 P.M.—"Anodic Oxide Films on Germanium"** by Solomon Zwerdling and Sumner Sheff, Lincoln Lab., Massachusetts Institute of Technology, Lexington, Mass. (Abstract No. 60)

**3:30 P.M.—"Recent News" Papers.** Titles and short abstracts will be available at the registration desk.

## ELECTROTHERMICS AND METALLURGY

**Monday, April 30, 1956**

**Arcs in Inert Atmospheres and Vacuum—Arc Characteristics and Theory**

**with W. E. Kuhn presiding**

(ROOM OF THE DONS, Lobby)

**10:00 A.M.—Introductory Remarks** by W. E. Kuhn, Research and Development Div., Carborundum Co. Inc., Niagara Falls, N. Y.

**10:20 A.M.—"Characteristics of High Current Arcs for Consumable Electrode Arc Melting"** by F. W. Wood and R. A. Beall, U. S. Bureau of Mines, Albany, Oreg.

(Abstract No. 61)

**10:50 A.M.—"Energy Transfer in the High Intensity Arc"** by Lawrence Mead, Marilyn A. Marquis, Charles Sheer, and Samuel Korman, Arc Research Dept., Vitro Labs., Vitro Corp. of America, West Orange Lab., West Orange, N. J.

(Abstract No. 62)

**11:20 A.M.—"A Descriptive Study of Consumable Electrode Arcs; the Pressure Dependence of Their Mode of Burn-Off—A Film"** by F. W. Wood and R. A. Beall, U. S. Bureau of Mines, Albany, Oreg.

(Abstract No. 63)

**12:30 P.M.**—Society Luncheon and Business Meeting in Peacock Court (Lobby Floor).

**Electrothermics and Metallurgy**

**Monday, April 30, 1956**

**Arcs in Inert Atmospheres and Vacuum—Arc Characteristics and Theory** (cont'd)

**with P. C. Rossin presiding**

(ROOM OF THE DONS, Lobby)

**2:15 P.M.—"Effects of Magnetic Stirring on Titanium Ingot Quality"** by D. E. Cooper and R. J. Krieger, Titanium Metals Corp. of America, Henderson, Nev.
(Abstract No. 64)

**2:45 P.M.—"Properties of the Anode Flame of the High Intensity Arc"** by Marilyn A. Marquis, Lawrence Mead, Samuel Korman, and Charles Sheer, Arc Research Dept., Vitro Labs., Vitro Corp. of America, West Orange Lab., West Orange, N. J.
(Abstract No. 65)

**3:15 P.M.—"Characteristics of Consumable Electrode D-C Arcs in Argon"** by E. W. Johnson and G. T. Hahn, Research Labs., Westinghouse Electric Corp., Pittsburgh, Pa.
(Abstract No. 66)

**3:45 P.M.—"The Effect of Variables on the Melting Rate of Metals in the Consumable Electrode Arc Furnace"** by W. H. Smith and R. M. Parke, Research Lab., General Electric Co., Schenectady, N. Y.
(Abstract No. 67)

**Electrothermics and Metallurgy**

**Tuesday, May 1, 1956**

**Arcs in Inert Atmospheres and Vacuum—Arc Characteristics and Theory** (cont'd)

**with A. U. Seybolt presiding**

(ROOM OF THE DONS, Lobby)

**9:00 A.M.—"The High Intensity Arc in Process Chemistry"** by Charles Sheer and Samuel Korman, Arc Research Dept., Vitro Labs., Vitro Corp. of America, West Orange Lab., West Orange, N. J.
(Abstract No. 68)

**9:30 A.M.—"Arc Melting in a Vacuum"** by G. W. P. Rengstorff, Battelle Memorial Institute, Columbus, Ohio. (Abstract No. 69)

**10:00 A.M.—"Vacuum Remelting of Superalloys and Steels by the Consumable Electrode Process"** by W. W. Dyrkacz, Allegheny Ludlum Steel Corp., Watervliet, N. Y. (Abstract No. 70)

**10:30 A.M.—"Arc Properties in the Five Rare Gases"** by H. S. Morton and R. M. Gage, Linde Air Products Co., A Division of Union Carbide and Carbon Corp., Tonawanda, N. Y. (Abstract No. 71)

## Electrothermics and Metallurgy (cont'd)

### Tuesday, May 1, 1956

### Arcs in Inert Atmospheres and Vacuum—Furnace Design, Operation, and Applications

### with E. W. Johnson presiding

(ROOM OF THE DONS, Lobby)

**2:00 P.M.—"A Pilot Model Three-Phase A-C Consumable-Electrode Arc Furnace"** by P. C. Magnusson, G. L. Schmidt, F. Caputo, and R. A. Beall, U. S. Bureau of Mines, Albany, Oreg. (Abstract No. 72)

**2:30 P.M.—"A Vacuum Arc Melting Furnace for Refractory Metals"** by O. Z. Rylski and H. V. Kinsey, Physical Metallurgy Div., Dept. of Mines and Technical Surveys, Ottawa, Ont., Canada. (Abstract No. 73)

**3:00 P.M.—"Electrode Control Systems for Inert Atmosphere and Vacuum Furnaces"** by E. J. Borreback, Industrial Engineering Dept., Westinghouse Electric Corp., East Pittsburgh, Pa. (Abstract No. 74)

**3:30 P.M.—"The High Intensity Arc: Electrode Requirements for Metallurgical Applications"** by Samuel Korman and Charles Sheer, Arc Research Dept., Vitro Labs., Vitro Corp. of America, West Orange, N. J. (Abstract No. 75)

**Electrothermics and Metallurgy** (cont'd)

**Monday, April 30, 1956**

**Marginal Ores and Their Relationship to the National Economy**

**with A. H. Roberson presiding**

(GOLDEN EMPIRE ROOM, Mezzanine)

**10:00 A.M.—Introductory Remarks** by S. M. Shelton.

**10:10 A.M.—"A New Concept of Treating High Iron Bauxites in the Electric Furnace"** by M. J. Udy, Strategic-Udy Metallurgical Processes Ltd., Niagara Falls, Ont., Canada. (Abstract No. 76)

**10:35 A.M.—"Utilization of Siliceous Manganese Ores for Production of Silicomanganese"** by W. E. Anable, U. S. Bureau of Mines, Albany, Oreg. (Abstract No. 77)

**11:00 A.M.—"The Use of Waste Carbonaceous Materials in Electric Smelting"** by R. R. Rogers and G. E. Viens, Dept. of Mines and Technical Surveys, Ottawa, Ont., Canada. (Abstract No. 78)

**11:30 A.M.—"Alaska's Power Resources in Relation to Mineral Development"** by Ivan Bloch, Ivan Bloch and Associates, 611 Park Bldg., Portland, Oreg. (Abstract No. 79)

**12:30 P.M.**—Society Luncheon and Business Meeting in Peacock Court (Lobby).

**Electrothermics and Metallurgy**

**Monday, April 30, 1956**

**Marginal Ores and Their Relationship to the National Economy** (cont'd)

**with A. H. Roberson presiding**

(GOLDEN EMPIRE ROOM, Mezzanine)

**2:15 P.M.—"Production of Thorium"** by T. C. Runion and F. L. Cuthbert,

National Lead Co. of Ohio, Cincinnati, Ohio. (Abstract No. 80)

**2:45 P.M.—"Problems in the Extraction of Thorium and Rare Earth from Ores"** by H. E. Kremers, Lindsay Chemical Co., West Chicago, Ill. (Abstract No. 81)

**3:15 P.M.—"Processing of Alluvial Sands for the Recovery of Tantalum-Columbium Bearing Minerals"** by J. E. Shelton, U. S. Dept. of the Interior, Bureau of Mines, Albany, Oreg. (Abstract No. 82)

**3:45 P.M.—"Electrodeposition of Molybdenum"** by T. T. Campbell, U. S. Dept. of the Interior, Bureau of Mines, Albany, Oreg. (Abstract No. 83)

## Electrothermics and Metallurgy (cont'd)

### Wednesday, May 2, 1956

### Pyrometallurgical Refining of Reactor Fuels

### with Daniel Cubicciotti presiding

(GOLDEN EMPIRE AND BONANZA ROOMS, Mezzanine)

**9:00 A.M.—"Separation of Plutonium from Uranium by Distillation, Magnesium Extraction, and Salt Extraction"** by R. A. Barney, A. G. Buyers, D. Cubicciotti, F. J. Keneshea, A. Saul, and S. J. Yosim, Atomics International, Canoga Park, Calif. (Abstract No. 84)

**9:30 A.M.—"Precipitation Processes for Liquid Metal Fuels and Breeders"** by R. J. Teitel, Metallurgy Dept., Brookhaven National Lab., Upton, N. Y. (Abstract No. 85)

**10:00 A.M.—"Melt Refining of Uranium Metal"** by H. M. Feder, L. Burris, and N. Chellew, Argonne National Lab., Lemont, Ill. (Abstract No. 86)

**10:30 A.M.—"Uranium Hexafluoride Distillation"** by R. K. Steunenberg, Argonne National Lab., Lemont, Ill. (Abstract No. 87)

**11:00 A.M.—"Uranium Purification by Electrorefining"** by L. W. Niedrach and A. C. Glamm, Knolls Atomic Power Lab., Schenectady, N. Y. (Abstract No. 88)

**11:30 A.M.—"Liquid Metal Extraction of Reactor Fuels"** by A. F. Voigt, F. H. Spedding, A. H. Daane, and Others, Institute for Atomic Research, Iowa State College, Ames, Iowa. (Abstract No. 89)

**12:30 P.M.**—Electrothermics and Metallurgy Division Luncheon and Business Meeting in the Nob Hill Room, Fairmont Hotel. Speaker to be announced.

**Electrothermics and Metallurgy** (cont'd)

**Wednesday, May 2, 1956**

**Rare Earths**

**with W. H. Smith presiding**

(BONANZA ROOM, Mezzanine)

**2:00 P.M.—"Metallurgy and Physical Properties of Rare Earth Metals"** by F. H. Spedding, Iowa State College, Ames, Iowa. (Abstract No. 90)

**2:30 P.M.—"Flame Spectra of Some Rare Earths"** by A. W. Berger and T. F. Powers, Heavy Minerals Co., Chicago, Ill. (Abstract No. 91)

**3:00 P.M.—"A Caustic Process for the Treatment of Monazite and Xenotime"** by Paul Kruesi, Heavy Minerals Co., Chicago, Ill. (Abstract No. 92)

**3:30 P.M.—"Equilibrium and Kinetic Studies on the Praseodymium Oxide System"** by C. L. Sieglaff and L. Eyring, State University of Iowa, Iowa City, Iowa. (Abstract No. 93)

**4:00 P.M.—"Studies on Complex Formation in Lanthanon Aliphatic**

**Carboxylates"** by R. C. Vickery, Horizons Inc., Cleveland, Ohio.
(Abstract No. 94)

**Electrothermics and Metallurgy** (cont'd)

**Wednesday. May 2, 1956**

**Recent Developments in Super-refractories**

**with Winston Duckworth presiding**

(GOLDEN EMPIRE ROOM, Mezzanine)

**2:00 P.M.—"High Temperature Material Requirements in the Air Force"** by R. A. Jones, Materials Branch, Equipment Div., Air Research and Development Command, USAF, Baltimore, Md.
(Abstract No. 95)

**2:30 P.M.—"Recent Navy Evaluations of Ceramic and Cermet Materials"** by H. Hessing, Bureau of Aeronautics, Navy Dept., Washington, D. C., J. J. Harwood, Metallurgy Branch, Office of Naval Research, Navy Dept., Washington, D. C., and J. F. Erthal, Mechanical Properties Branch, Aeronautical Materials Lab., Naval Air Material Center, Philadelphia, Pa. (Abstract No. 96)

**3:00 P.M.—"Defect Structure and the Temperature Dependence of Strength of an Intermetallic Compound"** by J. H. Westbrook, Research Lab., General Electric Co., Schenectady, N. Y.
(Abstract No. 97)

**3:30 P.M.—"The Elastic Properties of Super-refractory Materials by a Sonic Method"** by S. M. Lang, Porcelain and Pottery Section, National Bureau of Standards, Washington, D. C. (Abstract No. 98)

**Electrothermics and Metallurgy**

**Thursday, May 3, 1956**

**Recent Developments in Super-refractories** (cont'd)

**with Winston Duckworth presiding**

(GOLDEN EMPIRE AND BONANZA ROOMS, Mezzanine)

**9:30 A.M.—"KT Silicon Carbide; A New High-Density Silicon Carbide Body"** by K. M. Taylor, The Carborundum Co., Niagara Falls, N. Y. (Abstract No. 99)

**10:00 A.M.—"Infiltrated Titanium Carbide—An Improved Cermet for Turbine Bladings"** by C. G. Goetzel, Sintercast Corp. of America, Yonkers, N. Y. (Abstract No. 100)

**10:30 A.M.—"The Effect of Particle Size on the Bulk Density and Strength Properties of Uranium Dioxide Specimens"** by M. D. Burdick and H. S. Parker, Porcelain and Pottery Section, National Bureau of Standards, Washington, D. C. (Abstract No. 101)

**11:00 A.M.—"Some Physical Properties of High-Density Thorium Dioxide"** by S. M. Lang and F. P. Knudsen, Porcelain and Pottery Section, National Bureau of Standards, Washington, D. C. (Abstract No. 102)

**Electrothermics and Metallurgy**

**Thursday, May 3, 1956**

**Recent Developments in Super-refractories** (cont'd)

**with Winston Duckworth presiding**

(GOLDEN EMPIRE AND BONANZA ROOMS, Mezzanine)

**2:00 P.M.—" 'Rockide' Coatings for Jet Nozzles"** by W. L. Howe, Norton Co., Worcester, Mass. (Abstract No. 103)

**2:30 P.M.—"The Status of Carbides, Borides, Cermets, and Intermetal-**

**lics for High Temperature Service"** by M. F. Judkins, New Products Div., Firth Sterling, Inc., Pittsburgh, Pa. (Abstract No. 104)

**3:00 P.M.—"Use of Cermets as Turbine Blades"** by G. C. Deutsch, Lewis Flight Propulsion Lab., Cleveland, Ohio (Abstract No. 105)

**3:30 P.M.—"Use of Super-refractories in Rocket Thrust Chambers"** by W. R. Sheridan, Rocket Materials and Propellants, Bell Aircraft Corp., Buffalo, N. Y. (Abstract No. 106)

## INDUSTRIAL ELECTROLYTIC

**Monday, April 30, 1956**

**Electrowinning and General**

**with W. D. Sherrow presiding**

(TERRACE ROOM, FAIRMONT HOTEL)

**2:15 P.M.—"A Commercial Process for Electrowinning Manganese"** by M. C. Carosella and R. M. Fowler, Electro Metallurgical Co., A Division of Union Carbide and Carbon Corp., Niagara Falls, N. Y. (Abstract No. 107)

**2:45 P.M.—"Current Efficiency of Anodic Oxide Coating Formation on Commercial Aluminum Alloys"** by G. H. Kissin and R. V. Paulson, Dept. of Metallurgical Research, Kaiser Aluminum & Chemical Corp., Spokane, Wash. (Abstract No. 108)

**3:15 P.M.—"The Structure of Kanigen"** by A. W. Goldenstein, G. Gutzeit, W. Rostocker, and F. Schossberger, Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill. (Abstract No. 109)

**3:45 P.M.—"Studies of a Vertical Rotary Mercury Cathode Cell"** by Shinzo Okada and Shiro Yoshizawa, Dept. of Industrial Chemistry, Faculty of Engineering, Kyoto University,

Yosida, Kyoto, Japan.

(Abstract No. 110)

**4:15 P.M.—"Electrolytic Production of Bromates"** by Takashi Osuga and Kiichiro Sugino, Sanwa Pure Chemicals Co. and Tokyo Institute of Technology, Tokyo, Japan.

(Abstract No. 111)

**Industrial Electrolytic** (cont'd)

**Tuesday, May 1, 1956**

**Fused Salt Electrolysis**

**with Milton Janes presiding**

(TERRACE ROOM, FAIRMONT HOTEL)

**9:30 A.M.—"Polarization in an Aluminum Reduction Cell"** by W. E. Haupin, Aluminum Research Labs., Aluminum Co. of America, New Kensington, Pa. (Abstract No. 113)

**10:00 A.M.—"Relation of Current Efficiency to Gas Composition in Aluminum Reduction Cells"** by T. R. Beck, Chemical Research Dept., Kaiser Aluminum & Chemical Corp., Permanente, Calif.

(Abstract No. 114)

**10:30 A.M.—"Electrolytic Preparation of Thorium-Bismuthide Dispersions in Bismuth for Blanket Preparation in the LMFR"** by M. A. Steinberg and M. E. Sibert, Horizons Inc., Cleveland, Ohio, and R. J. Teitel, Brookhaven National Labs., Upton, N. Y.

(Abstract No. 115)

**11:00 A.M.—"Evaluation of Electrolytic Parameters in the Preparation of Thorium Metal by Fused Salt Electrolysis"** by J. C. Bleiweiss, B. C. Raynes, and M. A. Steinberg,

Horizons Inc., Cleveland, Ohio.
(Abstract No. 116)

**12:30 P.M.**—Industrial Electrolytic Division Luncheon and Business Meeting, Nob Hill Room, Fairmont Hotel. W. C. Gardiner will give the Chlor-Alkali Committee Report.

## Industrial Electrolytic

### Tuesday, May 1, 1956

### Fused Salt Electrolysis (cont'd)

### with J. C. Schumacher presiding

(TERRACE ROOM, FAIRMONT HOTEL)

**2:00 P.M.**—**"The Mobility of the Ions in Silver Nitrate-Alkali Nitrate Mixtures"** by F. R. Duke, Nobel Ida, and Boone Owens, Iowa State College of Agriculture and Mechanic Arts, Ames, Iowa.
(Abstract No. 117)

**2:30 P.M.**—**"The Mechanism of Titanium Production by Electrolysis of Fused Halide Baths Containing Titanium Salts"** by J. G. Wurm, Lucien Gravel, and R. J. A. Potvin, Laval University, Quebec, Que., Canada. (Abstract No. 118)

**3:00 P.M.**—**"The Electrorefining of Titanium in Fused Salt Media"** by D. H. Baker, Jr., and J. R. Nettle, Electrometallurgical Experiment Station, Bureau of Mines, U. S. Dept. of the Interior, Boulder City, Nev.
(Abstract No. 119)

**3:30 P.M.**—**"The Mechanism of Deposition of Titanium Coatings from Fused Salt Baths"** by M. E. Straumanis, S. T. Shih, and A. W. Schlechten, Dept. of Metallurgy, University of Missouri School of Mines and Metallurgy, Rolla, Mo.
(Abstract No. 120)

**4:00 P.M.**—**"Deposition of Titanium from Titanium-Oxygen Alloys on Copper, Iron, and Mild Steel"** by

S. T. Shih, M. E. Straumanis, and A. W. Schlechten, Dept. of Metallurgy, University of Missouri School of Mines and Metallurgy, Rolla, Mo.
(Abstract No. 121)

**Joint Symposium**

## THEORETICAL ELECTRO-CHEMISTRY AND CORROSION

**Monday, April 30, Tuesday, May 1, 1956**

**Adsorption Phenomena at Electrode Surfaces**

(BONANZA ROOM, Mezzanine)

*See* Corrosion-Theoretical Electrochemistry, Joint Symposium, page 15*C*.

## THEORETICAL ELECTRO-CHEMISTRY

**Wednesday, May 2, 1956**

**with Ernest Yeager presiding**

(ROOM OF THE DONS, Lobby)

**9:00 A.M.—"A Study of the Cathodic Reduction of Oxide Films on Iron, II. The Reduction of Magnetite"** by H. G. Oswin, Dept. of Metallurgical Research, Kaiser Aluminum & Chemical Corp., Spokane, Wash.
(Abstract No. 122)

**9:30 A.M.—"Mechanisms of Hydrogen Producing Reactions on Palladium, II. Diffusion of Electrolytic Hydrogen through Palladium"** by Sigmund Schuldiner and J. P. Hoare, Naval Research Lab., Washington, D. C. (Abstract No. 123)

**10:00 A.M.—"Mechanisms of Hydrogen Producing Reactions on Palladium, III. Hydrogen Overvoltage on the Polarization and Diffusion Sides of a Cathode-Diaphragm"** by

J. P. Hoare and Sigmund Schuldiner, Naval Research Lab., Washington, D. C. (Abstract No. 124)

**10:30 A.M.—"Mechanisms of Hydrogen Producing Reactions on Palladium, IV. Potential of the Alpha-Palladium/Hydrogen Electrode"** by Sigmund Schuldiner and J. P. Hoare, Naval Research Lab., Washington, D. C. (Abstract No. 125)

**11:00 A.M.—"Comparison of the Variations of the Direct Method of Measuring Polarization, I. Potentiometric Study with Copper Electrodes in Acid Copper Sulfate Solution"** by A. L. Ferguson and L. O. Case, University of Michigan, Ann Arbor, Mich., and R. S. Karpiuk, Dow Chemical Co., Midland, Mich. (Abstract No. 126)

**11:30 A.M.—"Comparison of the Variations of the Direct Method of Measuring Polarization, II. Oscillographic Study with Copper Electrodes in Acid Copper Sulfate Solution"** by A. L. Ferguson and L. O. Case, University of Michigan, Ann Arbor, Mich., and R. S. Karpiuk, Dow Chemical Co., Midland, Mich. (Abstract No. 127)

**Theoretical Electrochemistry** (cont'd)

**Wednesday, May 2, 1956**

**with Sigmund Schuldiner presiding**

(ROOM OF THE DONS, Lobby)

**2:00 P.M.—"Hydrogen Overvoltage on Lead"** by Edward Kure, Ernest Yeager, and Frank Hovorka, Dept. of Chemistry, Western Reserve University, Cleveland, Ohio. (Abstract No. 128)

**2:30 P.M.—"Hydrogen Overvoltage on Nickel"** by Richard Jefferys, Ernest Yeager, and Frank Hovorka, Dept. of Chemistry, Western Reserve University, Cleveland, Ohio.

(Abstract No. 129)

**3:00 P.M.—"Molecular Desorption as a Rate-Determining Step for Hydrogen Overvoltage on Platinum"** by Gerald Lozier, Ernest Yeager, and Frank Hovorka, Dept. of Chemistry, Western Reserve University, Cleveland, Ohio.

(Abstract No. 130)

**3:30 P.M.—"Nitrogen Overpotential on Bright Platinum in Liquid Ammonia Solutions"** by Morris Eisenberg, Stanford Research Institute, Menlo Park, Calif.

(Abstract No. 131)

**4:00 P.M.—"High Current Electronic Interrupter for the Study of Electrode Processes"** by W. E. Richeson and Morris Eisenberg, Stanford Research Institute, Menlo Park, Calif. (Abstract No. 132)

**4:30 P.M.—"Diffusion-Controlled Metal Deposition on Stationary Microelectrodes"** by T. Pavlopoulos and J. D. H. Strickland, British Columbia Research Council, University of British Columbia, Vancouver, B.C., Canada.

(Abstract No. 133)

**Theoretical Electrochemistry** (cont'd)

**Thursday, May 3, 1956**

**with C. V. King presiding**

(ROOM OF THE DONS, Lobby)

**9:30 A.M.—"Problems of Electrochemical Nomenclature and Definitions"** by Pierre Van Rysselberghe, Dept. of Chemistry, University of Oregon, Eugene, Oreg.

(Abstract No. 134)

**10:00 A.M.—"Mathematical Studies on Galvanic Corrosion, V. Calculation of the Average Value of the Corrosion Current Parameter"** by J. T. Waber, John Morrissey, and John Ruth, Los Alamos Scientific Lab.,

University of California, Los Alamos, N. Mex. (Abstract No. 135)

**10:30 A.M.—"The Anode Behavior of Germanium in Aqueous Solutions"** by D. R. Turner, Bell Telephone Labs., Inc., Murray Hill, N. J. (Abstract No. 136)

**11:00 A.M.—"Electrokinetic Potentials on Bulk Metals by Streaming Current Measurements, II. Gold, Platinum, and Silver in Dilute Aqueous Electrolytes"** by R. M. Hurd and Norman Hackerman, Defense Research Lab. and Dept. of Chemistry, University of Texas, Austin, Texas. (Abstract No. 137)

**11:30 A.M.**—Theoretical Electrochemistry Division Business Meeting.

**Theoretical Electrochemistry** (cont'd)

**Thursday, May 3, 1956**

**with C. V. King presiding**

(ROOM OF THE DONS, Lobby)

**2:00 P.M.—"Electrolytes of Binary Solutes in Ketones"** by J. E. Lilienfeld, Helen Y. Hsiao, and H. S. Myers, Power Condenser and Electronics Corp., Washington, D. C. (Abstract No. 138)

**2:30 P.M.—"The Allotropic Modifications of Calcium"** by J. F. Smith, O. N. Carlson, and R. W. Vest, Institute for Atomic Research and Dept. of Chemistry, Iowa State College, Ames, Iowa. (Abstract No. 139)

**3:00 P.M.—"A Proposed Mechanism for the Electrolytic Conductance of Soda-Silica Glasses"** by A. B. Rothman, Research Labs., Pittsburgh Plate Glass Co., Creighton, Pa. (Abstract No. 140)

**3:30 P.M.—"Electrochemical Properties of a Cation-Transfer Membrane"** by N. W. Rosenberg, J. H. B. George, and W. D. Potter, Ionics. Inc., Cambridge, Mass.

(Abstract No. 141)

**4:00 P.M.—"Electrochemistry Applied to Electrophysiology"** by R. H. Beutner, Medical Research Lab., Des Moines Still College of Osteopathy and Surgery, Des Moines, Iowa. (Abstract No. 142)

# ABSTRACTS

## CORROSION — THEORETICAL ELECTROCHEMISTRY

**Abstract No. 1**

### SURVEY OF THE WORK ON POLARIZATION OF IRON ELECTRODES IN ACID SOLUTIONS

**K. F. Bonhoeffer**

The report is restricted to polarization phenomena on pure iron in acid solutions of $p\mathrm{H} < 4$ which contain neither oxygen nor other depolarizers. Higher anodic polarization currents leading to surface layers or passivity are excluded from consideration. Based on new experiments of Kaesche, anodic hysteresis phenomena are discussed in detail. It is suggested the adsorbed and dissolved hydrogen is responsible for these effects.

**Abstract No. 2**

### ADSORPTION OF POLYELECTROLYTES ON A MERCURY SURFACE

**D. C. Grahame and I. R. Miller**

Differential capacities of the electrical double layer at the boundary between mercury and aqueous solutions of $0.09N$ $NaClO_4$ + $0.01N$ $HClO_4$ containing various concentrations of polymethacrylic acid have been measured. Results indicate the existence at the interface of a "surface phase" composed of molecules bound to the metal by a multiplicity of individually weak bonds. The act of forming and breaking these bonds involves an activation energy presumed to be related to the associated reorientation of the adsorbed molecules.

**Abstract No. 3**

## ADSORPTION AND CORROSION

**Norman Hackerman**

In corrosion reactions of adsorption a foreign substance may interfere with material transport or alter the activity of the metal. In the first case, the effect on open-circuit potential should be small, although there might be a major influence on polarization of a gas-producing reaction. In the second case, the effect on open-circuit potential should be larger. "Surface complexes" are discussed in some detail in terms of the above effects.

**Abstract No. 4**

## THE HEAT AND SURFACE POTENTIAL OF ADSORPTION OF HYDROGEN ON MERCURY

**J. O'M. Bockris and J. T. Law**

The heat of adsorption of hydrogen and the dipolar nature of the metal-hydrogen bond are of considerable importance in the evaluation of the heat of activation in the hydrogen evolution reaction. These quantities have been measured under conditions of high purity at an Hg surface, and the results applied to the elucidation of the mechanism of proton discharge.

**Abstract No. 5**

## HYDROGEN EVOLUTION KINETICS AND THE THERMIONIC WORK FUNCTION

**B. E. Conway and J. O'M. Bockris**

The rate of hydrogen evolution at electrodes increases with the electronic work function. Desorption rates would, however, be expected to decrease with increasing hydrogen adsorption energy. The anomaly is explained by the dependence of hydrogen adsorption energy

on coverage and by proton diffusion through the metal surface with metallic orbital formation by the hydrogen electron with the metal *d*-bands. The model indicates the distribution of mechanisms for the hydrogen evolution reaction as a function of the *d*-band character of the metal substrate.

**Abstract No. 6**

## ADSORPTION AND POLAROGRAPHY

**Paul Delahay**

Some characteristics of electrode processes with partial or total diffusion control are discussed for the following cases: (*a*) adsorption of a nonreducible (or nonoxidizable) substance; (*b*) reduction of an unadsorbed substance in presence of an adsorbed nonreducible substance; (*c*) reduction of an adsorbed substance. Treatments are given, whenever feasible, for electrolysis at constant potential, at constant current, and with superimposed alternating component. Experimental results and applications are described briefly.

**Abstract No. 7**

## ANODIC OXIDATION OF VARIOUS METALS AT VERY LOW CURRENT DENSITIES

**H. Johansen, G. B. Adams, Jr., and Pierre Van Rysselberghe**

Recent research in the anodization of metals is briefly reviewed. Data concerning the anodic polarization of aluminum, titanium, hafnium, chromium, vanadium, niobium, and tantalum in ammonium borate solution for the range 0–100 $\mu$a current density are presented. Local currents for the free corrosion of the metals are estimated. A comparison of the formation rates of five of these metals is made on

the basis of the Mott-Cabrera theory of metal oxidation.

**Abstract No. 8**

## INHIBITION OF IRON CORROSION IN ACID SOLUTIONS*

**Cecil V. King and Eric Rau**

The inhibition of iron dissolution from rotating cylinders has been studied in solutions of dilute hydrochloric or perchloric acid with excess nitrate as depolarizer. No better oxidizing inhibitor than dichromate was found. Complexing and chelating agents greatly improve protection by dichromate in hydrochloric acid although they simultaneously shift the iron potential in the anodic direction. Iron is protected better by dichromate alone in perchloric acid; chelants tend to make the potential more cathodic, but shorten the time of protection.

Neocupferron, which forms insoluble chelate salts with iron ions, protects iron for many hours in these solutions. Carbon monoxide was studied as an adsorption inhibitor.

* Work done under Office of Ordnance Research Contract No. DA-30-069-ORD-1113.

**Abstract No. 9**

## ELECTRICAL DOUBLE LAYER CAPACITY AND SURFACE AREAS OF METALS

**Norman Hackerman and R. J. Brodd***

The relation between the polarization capacity of some metal electrodes, measured by a modification of the Bowden and Rideal method, and their surface area, measured in a specially constructed krypton adsorption unit, was investigated. The results are interpreted

* Present address: National Bureau of Standards. Washington 25, D. C.

with the aid of the relationship between the work function of a metal and the potential of its electrocapillary maximum and the electrocapillary behavior of mercury.

**Abstract No. 10**

## OXYGEN OVERVOLTAGE IN CONCENTRATED ACID SOLUTIONS

### I. Perchloric Acid

**T. R. Beck* and R. W. Moulton**

Oxygen overvoltage was measured on platinum electrodes in 5M perchloric acid from −45° to +40°C and in 0.005–9M perchloric acid at 0°C. A limiting current density that was found is due to activation overvoltage at the anode surface. This limiting current density decreased at lower temperatures and in higher perchloric acid concentrations. It also marked the beginning of ozone formation. Adsorption of perchlorate ions is believed to be the cause of the limiting current density.

* Present address: Kaiser Aluminum & Chemical Corp., Permanente, Calif.

**Abstract No. 11**

## INHIBITORY PROCESSES AT THE DROPPING MERCURY ELECTRODE

### I. Structure of the Adsorbed Layer of Pyridine

**L. Gierst* and D. Bermane**

The surface excess of pyridine in alkaline solutions has been evaluated using electrocapillary measurements. The data obtained show that, after a critical amount of pyridine has been added, the

* Present address: Faculté des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium.

quantity adsorbed becomes independent of further addition of pyridine and of the applied potential. These and other results lead to the conclusion that the adsorbed layer is monomolecular, close-packed, and oriented. A theoretical treatment is suggested to describe the properties of the organic adsorbed layer.

**Abstract No. 12**

## INHIBITORY PROCESSES AT THE DROPPING MERCURY ELECTRODE

### II. Inhibition of the Discharge of $PbO_2H^-$ by Pyridine

**L. Gierst* and D. Bermane**

The influence of increasing quantities of pyridine on the discharge of $PbO_2H^-$ in alkaline solutions has been studied using polarography and electrolysis simultaneously under constant current in unstirred solutions. From the kinetic data, the inhibition appears to proceed according to three different mechanisms, depending on the potential and the quantity of pyridine added. Results are consistent with the electrocapillary data, previously reported. Electrolysis under constant current in unstirred solutions is adequate to study the kinetics of irreversible reactions and permits, in particular, one to distinguish quantitatively between the several types of inhibitory processes.

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* Present address: Faculté des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium.

**Abstract No. 13**

## RADIO-TRACER TECHNIQUE FOR CONTINUOUS MEASUREMENTS, IN SITU, OF ADSORPTION FROM SOLUTIONS

**M. T. Simnad**

An experimental technique has been developed to measure continuously the rates of adsorption of tagged ions from solutions on metal surfaces. The method can be used to study the rates of exchange, adsorption, and passivity. Preliminary results show that previous measurements of the activity of washed specimens are unreliable and are of qualitative value only, since variable amounts of the adsorbed layers are removed by washing. Theories based on such measurements are also of questionable value.

**Abstract No. 14**

### KINETICS OF SILVER-SILVER ION EXCHANGE

**C. V. King and Ann-Mari Simonsen**

Silver exchanges rapidly with its ions on initial immersion in solution, with much slower exchange thereafter. In the present work, silver coupons were given repeated brief immersions in radiosilver nitrate solutions of four concentrations, with hot and cold water washing. The initial exchange was found to be of first order kinetically with one immersion as the time unit and maximum exchange corresponding to 35 to 50 atomic layers based on measured area. Measurement of the slow exchange indicates an exchange current density of $40 \times 10^{-10}$ amp/cm$^2$ in 0.5*N* silver nitrate.

## ELECTRIC INSULATION

**Abstract No. 15**

### BIOLOGICAL INSULATING MATERIALS

**R. N. Hazelwood**

The properties and characteristics of electrical insulating materials in biological systems are reviewed. The func-

tion of lipids and lipoproteins in nerve conduction is discussed. Current work on the role of insulators in the photochemical reactions of photosynthesis will be described. Ultracentrifugal characterization of lipoproteins will be discussed.

**Abstract No. 16**

## DIELECTRIC STRENGTH OF INSULATION SYSTEMS

**D. A. Lupfer**

(No abstract received)

**Abstract No. 17**

## THERMAL EVALUATION OF INSULATION

**E. L. Brancato**

Advances in the evaluation of insulation systems are discussed and the present status of magnet wire, motorette, and motor aging studies is reported.

**Abstract No. 18**

## THERMAL EXPANSION OF FILLED EPOXY RESINS

**J. E. Carey**

This paper discusses the importance of filler choice in formulating epoxy resins for encapsulation operations and presents some data on thermal coefficient of expansion vs. filler type and resin content.

**Abstract No. 19**

## ELECTRICAL PROPERTIES OF SOME EPOXY RESINS

**C. H. Klute**

Epoxy resins are still relative newcomers to the field of electrical insulating materials. For this reason detailed information concerning their response

to alternating current is not as readily available as is that for other common insulators. This paper is a report of progress of a continuing study of the electrical behavior of the EPON Resins manufactured by Shell Chemical Corp. The study is restricted at present to the low molecular weight species used in electrical casting compounds and will attempt to point out the electrical properties developed in the solid material when crosslinking is induced by each of three important types of amine catalysts, viz., amines with active amine hydrogen, tertiary amines, and amine salts.

**Abstract No. 20**

## CHARACTERISTICS OF MULTILAYER DIELECTRICS

**D. A. Lupfer**

(No abstract received)

**Abstract No. 21**

## APPLICATION OF INSULATORS AND WINDOW PROBLEMS IN VACUUM TUBES AT MICROWAVE FREQUENCIES

**E. T. Jaynes**

(No abstract received)

**Abstract No. 22**

## EFFECT OF VOLTAGE AT ELEVATED TEMPERATURES ON INSULATION RESISTANCE OF CERAMIC CAPACITORS

**K. H. Brandt**

(No abstract received)

**Abstract No. 23**

## MICROSTRUCTURE OF BARIUM TITANATES CERAMICS

**I. E. Burkes and R. C. de Vries**

(No abstract received)

**Abstract No. 24**

PHASE EQUILIBRIA AND SOLID-STATE REACTIONS IN THE SYSTEM OF TALC-CLAY

**J. A. Pask**

(No abstract received)

**Abstract No. 25**

ELECTROCHEMICAL ETCHING OF HIGH PURITY ALUMINUM CAPACITOR FOIL IN SODIUM CHLORIDE SOLUTIONS

**G. H. Kissin and Gloria S. Murphy**

The influence of electrolyte concentration, temperature, current density, and time was investigated for the anodic etching in sodium chloride solutions of 99.80, 99.87, and 99.99% aluminum foil. Metallographic examination and capacitance measurements of etched surfaces anodized in boric acid showed that the extent of etching and the configuration of the etched surfaces varied as the purity of the foil was changed. Optimum etching conditions for maximum increase in surface area were determined for application to the production of electrolytic capacitor anodes.

## ELECTRONICS—LUMINESCENCE

**Abstract No. 26**

POTENTIALITIES AND DIFFICULTIES IN THE INTERPRETATION OF THE KINETICS OF LUMINESCENCE

**M. Schön**

(No abstract received)

**Abstract No. 27**

RADIATION RESULTING FROM THE RECOMBINATION OF HOLES AND ELECTRONS IN SILICON

**J. R. Haynes**

Radiation produced by the recombination of excess electrons and holes in silicon has been examined both at room temperature and at 77°K. The radiation obtained at room temperature is shown to be an intrinsic property of silicon. It is probably due to indirect transitions of electrons from the conduction band minima to the valence band with phonon cooperation. Additional radiation is found at 77°K which is structure sensitive. This radiation is shown to be produced by the recombination of excess carriers with un-ionized donor and acceptor impurities. Differences between the photon energies associated with the maximum photon emission of intrinsic and extrinsic radiation are in semiquantitative accord with accepted values of ionization energies of the donor and acceptor impurities introduced in the crystal growing process.

**Abstract No. 28**

## PHYSICAL BASIS OF A MULTIPHONON PROCESS

**J. J. Markham**

Low temperature experiments in the alkali halide indicate that there must be a way for an electron to generate many phonons simultaneously when it drops from one state to another. A series of single phonon processes is believed to be too slow to explain the observations. The author attempts to give the physical basis of a multiphonon process by the use of Franck-Condon diagrams. This suggests why it should be a common phenomenon in solids.

**Abstract No. 29**

## THERMOLUMINESCENCE OF MANGANESE-ACTIVATED CALCIUM FLUORIDE

R. J. Ginther and R. D. Kirk

The thermoluminescence of manganese-activated calcium fluoride has been investigated as a possible method for dosimetry of x-rays and gamma rays. It was found that samples containing from 1.0 to 5.0% Mn have a single glow peak at about 250°C. Samples of lower manganese concentration have low temperature emission peaks which render the dosage indication unstable through the thermal release of electrons from shallow traps. The presence of alkali impurities or of cerium shifts the thermoluminescence to lower temperatures, whereas concentrations of manganese above the optimum or the use of commercial materials in the synthesis result in poor efficiency.

**Abstract No. 30**

## THERMOLUMINESCENCE OF TITANIUM-ACTIVATED LITHIUM SILICATES

P. J. Pizzolato

Thermoluminescent properties of titanium-activated lithium metasilicate phosphor make it of potential usefulness as a radiation dosimeter. This material has its main glow peak at 250°C and a smaller one at 90°C. Other titanium-activated lithium silicate systems, the disilicate and orthosilicate, were found to have lower sensitivities to gamma and x-radiation and less favorable glow curves. Initial work has shown a clearly measurable response to gamma ray doses as low as 10 roentgens ($Co^{60}$), a response nearly proportional to dose applied, stability of the high temperature glow peak on storage, and dose rate independence. These preparations were found to be energy independent in the range 100 kev to 1.2 mev, and the response to a given dose of 38 kev x-rays was five

times that of an equivalent dose of 1.2 mev gamma rays.

**Abstract No. 31**

## PREPARATION OF THE SELENIDES OF HYDROGEN AND ZINC

**G. E. Crosby**

The need for hydrogen and zinc selenide necessitated the study of various techniques for preparing these compounds. A report of a literature survey and a laboratory evaluation of many processes are given. Some processes are reported for preparing luminescent grade zinc selenide directly from selenium without use of the toxic hydrogen selenide.

**Abstract No. 32**

## PREPARATION OF THE COPPER-ACTIVATED ZINC SELENIDE PHOSPHOR BY THE DRY PROCESS

**G. E. Crosby**

A dry process is described which yields the zinc selenide phosphor with luminescent properties equivalent to the same phosphor prepared from precipitated selenide. Optimum conditions for preparation and optimum chemical concentrations are discussed.

**Abstract No. 33**

## ULTRAVIOLET FLUORESCENCE OF SOME TERNARY SILICATES ACTIVATED WITH LEAD

**H. A. Klasens, A. H. Hoekstra, and A. P. M. Cox**

The investigation of the phase diagrams of ternary systems containing $SiO_2$, one oxide of the group (CaO, SrO, BaO), and MgO or ZnO has led to the discovery of eleven new compounds some of which proved to be very good base ma-

terials for Pb-activated phosphors with emissions ranging from 3000 to 4000 Å. A suitable phosphor for "sun lamps" is $Ba(Zn, Mg)_2Si_2O_7$—Pb, for "black light lamps", $Sr_{0.6}Ba_{1.4}(Zn, Mg)Si_2O_7$—Pb.

**Abstract No. 34**

## ALKALI COMPENSATED SILICATE PHOSPHOR

**G. E. Crosby**

Results of incorporating alkali ions into cerium-activated calcium magnesium silicate (Akermanite) phosphor are reported and discussed. Alkali ion compensation of the silicate phosphor yielded a product with greater luminescent efficiency and slightly shorter decay. Incorporation of alkali ion on preparation greatly improved the yield of good phosphor.

**Abstract No. 35**

## AN AUTOMATIC RECORDING RADIOMETER

**A. E. Martin, C. E. Meinheit,* and F. W. Harjes†**

An automatic radiometer has been built for direct recording of excitation spectra of photoluminescent phosphors. Narrow bands of ultraviolet radiation provide the excitation. The central wave length of such bands lies within the limits 2200–4500 Å. The accuracy of the excitation efficiency is 5%. Another function readily provided is automatic recording of emission spectra of phosphors within the range 3300–6650 Å. The precision of recorded functions is approximately 1%. Absorption data can also be taken, although at reduced accuracy.

*Present address: Sylvania Electric Products Inc., Mineola, N. Y.

† Present address: Sylvania Electric Products Inc., Kew Gardens, N. Y.

**Abstract No. 36**

## SOME PRACTICAL ASPECTS OF ELECTROPHORETIC DEPOSITION

**G. F. Kinney and J. V. Festa**

Typical electrophoretic deposits employed in the electron tube industry are described with regard to suspension composition, equipment required, and nature of deposits obtained. The effect of added moisture and the effect of partial settling also were investigated. It is pointed out that the three electrode processes, neutralization of charged particles, their deposition, and the electrode reaction, although occurring concurrently, can well occur independently.

**Abstract No. 37**

## INFLUENCE OF CONVECTION AND OTHER FACTORS IN FLUORESCENT SCREEN UNIFORMITY

**P. R. Myers and C. T. Lattimer**

Television tube manufacture requires the application of screens with uniform weight-per-unit-area characteristics to provide a uniform screen color across the entire tube face. This paper covers an investigation of the effect of convection currents on screen weight uniformity from the theoretical and practical viewpoints. Studies of liquid movement by dye tracers and thermal gradients are presented along with screen application tests which culminated in screens of excellent weight uniformity through convection current assistance.

**Abstract No. 38**

## TIME-AVERAGE ELECTROLUMINESCENCE OUTPUT OF SOME ZINC SULFIDE PHOSPHORS

**Sol Nudelman and Frank Matossi**

The dependence of time-average electroluminescence output on field strength

and frequency is observed for frequencies up to 20 kcps for green and blue emission. Field dependence can be described either by a power law or by an exponential law. The frequency dependence is discussed in terms of theoretical relations (Curie) connecting the light output to recombination characteristics or to polarization effects. Light output from sinusoidal and square wave excitation is compared.

**Abstract No. 39**

## ELECTROLUMINESCENCE OF ZINC SULFO-SELENIDE PHOSPHORS WITH COPPER ACTIVATORS AND HALIDE COACTIVATORS

**I. J. Hegyi, S. Larach, and R. E. Shrader**

Spectral distributions and emission intensities of Zn(S:Se):Cu phosphors will be discussed in detail. Both the color and intensity of emission are affected by the halide used as a coactivator. A decrease in the dominant wave length of emission is obtained in varying the coactivator from chloride to bromide to iodide. Higher intensity of emission is found when iodide is used as a coactivator in ZnS:Cu phosphors, and when bromide is used as a coactivator in Zn(S:Se):Cu phosphors. A red-emitting electroluminescent material will be described.

**Abstract No. 40**

## PHYSICOCHEMICAL ASPECTS OF ELECTROLUMINESCENCE OF ZINC SULFIDE PHOSPHORS WITH COPPER ACTIVATOR

**S. Larach, R. E. Shrader, and I. J. Hegyi**

The role of the copper activator and of the halide flux in electroluminescent

ZnS:Cu will be discussed from a physicochemical point of view. The effect of the flux on the amount of copper incorporated into ZnS will be described. Electroluminescence will be described in terms of a model which involves both copper and halide. Chemical barriers and other surface effects will be discussed.

**Abstract No. 41**

## FURTHER EXPERIMENTS ON ELECTROLUMINESCENCE OF ZnS SINGLE CRYSTALS

**D. R. Frankl**

The major features of the light emission and current in electroluminescent ZnS crystals were discussed at the 1955 meeting. Refinements in technique have made possible the study of some of the less prominent features, including a small permanent polarization and several additional emission peaks. In addition, further studies of the dependence of the major emission peaks on voltage, waveform, and temperature have been made. These experimental results will be described and interpretations offered where possible.

**Abstract No. 42**

## A THEORY OF THE ELECTROLUMINESCENCE OF ZnS SINGLE CRYSTALS

**J. L. Birman**

Field stabilization of traps and current excitation of centers, proposed as mechanisms involved in the electroluminescence of ZnS, have been tested on a model of a luminescent center consisting of three energy levels (ground, intermediate, and trap states) subject to periodic half-wave and d-c applied voltages. The results of the test, which will be discussed and compared with experiment, include the dependence of: (*a*)

shape of the brightness wave; (*b*) magnitude of the brightness maxima; and (*c*) integrated brightness per cycle, on peak voltage, temperature, and frequency.

**Abstract No. 43**

## SOME EXPERIMENTS ON PERSISTENT POLARIZATION AND PHOTOCONDUCTIVITY IN ZnS CRYSTALS

**A. Lempicki**

Certain ZnS synthetic crystals polarize under the influence of an electric field applied in the dark, and remain polarized for a long time after removal of the field. When the field is applied while the crystals are illuminated, polarization is much larger. High photocurrents can flow even when the crystal is polarized. Under illumination, polarization increases sublineally and the photocurrents superlineally with voltage. Shapes of photocurrent pulses under illumination of various wave lengths, and the effects of polarization thereon, are discussed.

**Abstract No. 44**

## INCORPORATION OF CHLORIDE IN ZnS PHOSPHOR PREPARATION

**A. Kremheller, A. K. Levine, and D. J. Bracco**

Data are presented on recent investigations of the mechanism of the incorporation of chloride into zinc sulfide powders during firing. In continuation of previously reported work it is found that the temperature dependence of the retention of volume chloride in zinc sulfide is similar whether the flux is NaCl or $ZnCl_2$; the volume chloride shows a peak concentration near 500°C in both cases.

**Abstract No. 45**

### THE RELEASE OF CHLORIDE FROM ZINC SULFIDE BY GRINDING

**A. Kremheller and A. K. Levine**

Grinding, followed by displacement washing, permits one to distinguish between lattice and internal surface chloride in ZnS powder fired with chloride flux. Data are presented on the amount of removable chloride for ball milling times up to 300 hr.

## ELECTRONICS—SEMICONDUCTORS

**Abstract No. 46**

### SURFACE STATES ON SEMICONDUCTORS

**J. Bardeen**

The following measurements have been used by various investigators to determine concentrations, energies, and trapping cross sections of surface states: (*a*) surface conductance and its variation with atmosphere and with applied external fields (field effect); (*b*) variation of conductance of an inversion layer with applied voltage (channel effect); (*c*) surface recombination; and (*d*) contact potential and change in contact potential with light. The present status of experimental results, mainly on germanium, and theoretical interpretation will be summarized.

**Abstract No. 47**

### ELEMENTAL SEMICONDUCTORS

**H. Y. Fan**

Bulk properties of elemental semiconductors, germanium and silicon, will be reviewed with emphasis on recent developments. Better knowledge of the energy band structure, energy gap, and effective mass has been obtained. Optical

absorption photoconductivity and spin resonance are used to study impurity states and lattice imperfections. Interesting observations have been made and better understanding obtained for various conduction phenomena, including magnetoresistance, thermoelectric power, high field and low temperature conductivity. Much has been learned about carrier recombination and trapping.

**Abstract No. 48**

## DEFECTS IN CRYSTALS OF SILICON AND GERMANIUM GROWN FROM THE MELT

**E. Billig**

Crystals of silicon and germanium have been grown from the melt under extreme conditions, and have been examined for crystal defects. Two specific types of defects could be introduced by varying growth conditions, and these were studied in great detail. Thin twin lamellae were produced by nucleation with a foreign impurity, while slip was produced by thermal stresses during crystal growth.

**Abstract No. 49**

## RECTIFYING SEMICONDUCTOR CONTACTS

A Review of Theoretical Progress

**H. K. Henisch**

The purpose of this paper is to acquaint nonspecialists in this field with the present state of understanding of rectifying contacts between metals and semiconductors. The subject is reviewed with special reference to contacts whose behavior is controlled by electric charges in surface states. Methods are outlined whereby some of the relevant parameters can be measured and the reliability of these procedures is discussed. Other

topics included in the survey are photoeffects, peak back turnover, and injection characteristics.

**Abstract No. 50**

## DISTRIBUTION OF COPPER BETWEEN GERMANIUM AND TERNARY MELTS SATURATED WITH GERMANIUM

**C. D. Thurmond and R. A. Logan**

The solubility of copper in solid germanium has been measured as a function of the copper concentration in ternary Ge-Cu-Pb melts saturated with germanium at 700°C. Alloys of Ge-Cu-In, Ge-Cu-Sn, and Ge-Cu-Au have also been studied but to a more limited extent. The distribution coefficient of copper as a function of melt concentration is explained in terms of the expected interactions deduced from the binary phase diagrams.

**Abstract No. 51**

## CONDUCTIVITY AND BAND GAP MEASUREMENTS OF SOME RELATIVES OF PHTHALOCYANINE

**Wolfgang Felmayer and Irving Wolf**

The electrical resistance of samples of powdered Cu-phthalocyanine, Pt-phthalocyanine, highly chlorinated Cu-phthalocyanine, and of two polymers of Cu-phthalocyanine were measured at various temperatures in a nitrogen atmosphere. All of the compounds showed semiconductive behavior. The highly chlorinated Cu-phthalocyanine and the Pt-phthalocyanine had approximately the same resistance as the Cu-phthalocyanine, whereas both polymers had lower resistances, one of the polymers having a resistance of about $10^{-3}$ that of Cu-phthalocyanine at various temperatures. Some theoretical implications of the above facts are mentioned.

**Abstract No. 52**

## TERNARY COMPOUND SEMICONDUCTORS WITH THE CHALCOPYRITE STRUCTURE

**I. G. Austin, C. H. L. Goodman, and A. E. S. Pengelly**

Energy gaps have been measured optically for five semiconducting compounds of chalcopyrite structure (a triply substituted diamond-type lattice). Measurements of mobility, photoconductivity, and temperature coefficient of the energy gap have been made on some of them. Their preparation was difficult because of vapor pressure effects. There was also a tendency for crack formation, believed to be due to differential thermal expansion in the polycrystalline specimens.

**Abstract No. 53**

## ELECTRONIC AND IONIC FLUCTUATION PROCESSES IN SEMICONDUCTORS

**R. E. Burgess**

The distribution of electrons between the conduction band, the valence band, and bound levels in a semiconductor exhibits: (*a*) spatial fluctuations due to unavoidable statistical inhomogeneity (chemical or physical) which are responsible for "patch" effects in semiconductor devices affecting particularly their reverse current and breakdown characteristics; and (*b*) temporal fluctuations which appear as noise and arise from the inevitable variations of the kinetics of electron-ion reactions about equilibrium. The theoretical foundations of these processes and a review of experimental data are presented.

**Abstract No. 54**

## INFLUENCE OF THE ABSORPTION EDGES OF CADMIUM AND SIL-

VER ON THE X-RAY DIFFRACTION PATTERN OF CADMIUM COMPOUNDS

**R. J. Robinson and F. Schossberger**

X-ray powder and rotation diagrams of hexagonal cadmium sulfide as obtained by Ni-filtered Cu K-OC radiation showed certain low angle lines and spots, respectively, which were tentatively explained by lattice imperfections or by the presence of an unknown modification. An analysis of the absorption conditions of the general radiation shows that the unique closeness of the absorption edges of cadmium (in the sample) and silver (in the film emulsion) could form a filter which selects a very narrow band of x-rays. The low angle diffraction phenomena then appear as Bragg reflections of hexagonal cadmium sulfide produced by an average wave length $\lambda = 0.475$ Å.

**Abstract No. 55**

## THE STATUS OF SEMICONDUCTOR TECHNOLOGY

**F. J. Biondi**

(No abstract received)

**Abstract No. 56**

## A METAL-SEMICONDUCTOR CAPACITOR

**R. L. Taylor and H. E. Haring**

A porous tantalum-tantalum oxide-manganese dioxide capacitor, which provides a far higher capacitance per unit of volume than can be obtained with any other capacitor heretofore available, will be described. Its size makes it extremely attractive for use in transistor circuits, and in other low voltage circuits requiring the ultimate in miniaturization. The construction, characteristics, and advantages of the new electronic device will be discussed.

**Abstract No. 57**

## DESIGN OF DIFFUSED JUNCTION SILICON DIODES

**H. S. Veloric and K. D. Smith**

Development in the diffusion technology of silicon $p$-$n$ junctions has made feasible a wide range of diffused junction silicon diodes with predictable breakdown characteristics. Units have been fabricated with breakdown voltages from 6 to 200 v and with areas from 100 square mils to 1 in.$^2$ A number of process parameters such as the nature of the diffusant, oven time and temperature, and the type of starting material are considered in the device design. Characteristics of some illustrative fabricated devices will be presented and compared with design theory.

**Abstract No. 58**

## SOME APPLICATIONS OF FIELD EFFECT STUDIES ON GERMANIUM SURFACES

**E. N. Clarke**

The field effect is time- and temperature-dependent and can be described by assuming that charge carriers are trapped in surface states. Recent results obtained in oxygen and in vacuum can be related to gas adsorption. Surface conduction induced by capacitively applied fields has proved useful in the study of excess currents on germanium $p$-$n$ junctions. In particular, the work to be discussed will show how one might distinguish between ionic and electronic currents in the presence of water vapor.

**Abstract No. 59**

## ANODIC OXIDATION OF SILICON

**P. F. Schmidt**

(No abstract received)

**Abstract No. 60**

## ANODIC OXIDE FILMS ON GERMANIUM*

**Solomon Zwerdling and Sumner Sheff**

Thick oxide films have been grown on *n*- and *p*-type germanium by anodizing in an anhydrous NaAc-HAc electrolyte. The films showed uniform interference colors in white light. The microgram quantity of oxidized germanium in each was determined colorimetrically. From this and corresponding values of anodic current density, duration of electrolysis, and rate of increase of anode voltage, the current efficiency, differential formation field, and resistivity of the oxide were calculated. Several intervals of different growth rate were found during the course of an electrolysis.

* The research reported in this document was supported jointly by the Army, Navy, and Air Force under contract with Massachusetts Institute of Technology.

# ELECTROTHERMICS AND METALLURGY—ARCS IN INERT ATMOSPHERES

## CHARACTERISTICS OF HIGH CURRENT ARCS FOR CONSUMABLE ELECTRODE ARC MELTING

**F. W. Wood and R. A. Beall**

A study has been made of consumable electrode arcs including rates of burnoff of anode and cathode at various subatmospheric pressures, with particular application to titanium and zirconium arc melting furnaces. A formula is proposed to describe the variation of burnoff with pressure, some related factors are discussed, and results of similar studies are reviewed.

**Abstract No. 62**

## ENERGY TRANSFER IN THE HIGH INTENSITY ARC

**Lawrence Mead, Marilyn A. Marquis, Charles Sheer, and Samuel Korman**

The mechanism whereby electrical input energy is transferred to electrode material in the high intensity arc is studied. Rapid vaporization of anode material is explained by abnormally high anode drop, effectively concentrating a major fraction of input energy on the electrode surface. A tentative explanation of subsequent superheating of anode vapor is given in terms of production and acceleration of ions in the fall space, followed by kinetic energy transfer from ions to neutral vapor.

**Abstract No. 63**

## A DESCRIPTIVE STUDY OF CONSUMABLE ELECTRODE ARCS; THE PRESSURE DEPENDENCE OF THEIR MODE OF BURN-OFF —A FILM

**F. W. Wood and R. A. Beall**

Through the use of high-speed cinematography, a study was made of the mechanisms of metal transfer in consumable electrode arcs, and their variation with relation to the change of pressure of the surrounding atmosphere. Film strips show arcs between electrodes of titanium and of iodide process zirconium.

**Abstract No. 64**

## EFFECTS OF MAGNETIC STIRRING ON TITANIUM INGOT QUALITY

**D. E. Cooper and R. J. Krieger**

In the consumable electrode arc melting process, use of a solenoid-type coil to induce stirring of the molten metal has been reported by various laboratories. This paper reports a study of the

stirring effect in a laboratory size furnace producing double-melted titanium ingots of 9½ in. and 12-in. diameter.

The degree of stirring is dependent on the magnetic field intensity of the coil and the arc current. In this study a series of ingots was melted at two levels of arc current and varying degrees of magnetic field intensity. In general, it was found that an optimum degree of stirring produced the best as-cast surface (least amount of porosity). Even a small amount of stirring breaks up the large columnar grains normally associated with the as-cast ingot, and the higher degrees of stirring produce the shallowest molten pools. A compromise between these effects was found to produce better results than no stirring or by too high a degree of stirring.

**Abstract No. 65**

## PROPERTIES OF THE ANODE FLAME OF THE HIGH INTENSITY ARC

**Marilyn A. Marquis, Lawrence Mead, Samuel Korman, and Charles Sheer**

A study is made of the thermal environment of material vaporized by the high intensity arc, with special emphasis on conditions prevailing in the anode tail flame. Using a steady-state approach, equations describing matter and energy balance of the anode flame are derived. Consequent effects of variation in power input, anode consumption rate, and ambient pressure on local temperature and matter density of the anode flame are examined and compared with experimental observations.

**Abstract No. 66**

## CHARACTERISTICS OF CONSUMABLE ELECTRODE D-C ARCS IN ARGON

**E. W. Johnson and G. T. Hahn***

Direct current arcs were struck in argon between horizontal electrodes of steel, titanium, molybdenum, tungsten, and graphite. The arc characteristics appeared to be determined primarily by the cathode material. With increasing cathode melting point the arcs became more stable and their heat distribution shifted markedly to favor the anode. These effects are apparent in color motion pictures of the respective arcs. The study is being extended to include arcs at reduced pressure.

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* Present address: Massachusetts Institute of Technology, Cambridge, Mass.

**Abstract No. 67**

## THE EFFECT OF VARIABLES ON THE MELTING RATE OF METALS IN THE CONSUMABLE ELECTRODE ARC FURNACE

**W. H. Smith and R. M. Parke**

The melting rates of metals in the consumable electrode arc process were determined as functions of the following variables: kind of metal, crucible to electrode size ratio, power input, melting pressure, and type of electrical circuit. Metals investigated were copper, iron, titanium, and molybdenum.

**Abstract No. 68**

## THE HIGH INTENSITY ARC IN PROCESS CHEMISTRY

**Charles Sheer and Samuel Korman**

The high intensity arc, or "Beck" arc, well known to illumination engineers, presents interesting applications in chemical and metallurgical processes. Unique arc properties make possible rapid and efficient vaporization of electrodes. Refractory materials, as consumable electrodes, can be vaporized,

reacted in homogeneous phase, and condensed, without contacting furnace walls, at power consumptions of 4–7 kwh/lb. Applications to ore reduction in inert atmosphere and vacuum, halogenation, and other chemical reactions will be described.

**Abstract No. 69**

## ARC MELTING IN A VACUUM

**G. W. P. Rengstorff**

Contrary to the general belief of a few years ago, metals can be arc melted in a good vacuum. Of course, the good vacuum (0.01 to 0.2 $\mu$ of mercury) is measured in the region above the arc. The arc itself is undoubtedly carried by metallic vapor from the electrode and the melt. This paper discusses some observations on the use of this metallic-vapor arc, particularly as applied to preparing high-purity molybdenum.

**Abstract No. 70**

## VACUUM REMELTING OF SUPERALLOYS AND STEELS BY THE CONSUMABLE ELECTRODE PROCESS

**W. W. Dyrkacz**

Various properties of steels and superalloys remelted in vacuo by the consumable electrode process have been investigated. Electrodes used for remelting are air-melted, alloyed cast ingots of desired composition. Data will cover several superalloys, low alloy, tool, and stainless steels. A comparison will be made between air-melted and vacuum remelted materials in mechanical properties, gas contents, and cleanliness as determined by inclusion ratings and forged upset tests. A high-speed motion picture film showing the arc melting operation in a research-type furnace will be shown.

**Abstract No. 71**

## ARC PROPERTIES IN THE FIVE RARE GASES

**H. S. Morton* and R. M. Gage**

High current arcs in the five rare gases have been studied. Voltage-current and voltage-arc length relationships are presented for currents from 50 to 400 amp DCSP, and for arc lengths of 0.025–1.0 in. A tungsten cathode with either a cold copper or a molten titanium anode was used. Calorimetric data are also given to show differences in heat dissipation to the anode and to the arc chamber.

* Present address: Oak Ridge Operations Office, U. S. Atomic Energy Commission, Oak Ridge, Tenn.

**Abstract No. 72**

## A PILOT MODEL THREE-PHASE A-C CONSUMABLE-ELECTRODE ARC FURNACE

**P. C. Magnusson, G. L. Schmidt, F. Caputo, and R. A. Beall**

Considerable advantage can be shown through use of alternating current with regard to the capital investment in a power supply for controlled atmosphere arc melting. The furnace described here not only utilizes alternating current, but yields a billet shaped ingot, appropriate for rolling directly, omitting the billeting step. This is accomplished by placing the three consumable electrodes in line, and melting with the a-c power supply connected in wye. Discussion is given of the electrical characteristics, and the feasibility of up-scaling the design.

**Abstract No. 73**

## A VACUUM ARC MELTING FURNACE FOR REFRACTORY METALS

**O. Z. Rylski and H. V. Kinsey**

An arc furnace for melting and alloying titanium and other metals in a protective atmosphere with continuous flushing at subatmospheric pressures is described. Some data on operational characteristics with different metals are presented.

The furnace is designed with the emphasis placed on adaptability to the diverse requirements of a research and development laboratory on a pilot-plant scale and can be used for consumable and nonconsumable electrode arc melting.

The exploratory results indicate high degree of soundness and good internal structure of metals arc-cast under reduced pressure and suggest a possibility of commercial application in such fields of metal industry where gaseous inclusions and reactive characteristics of metals are of importance.

**Abstract No. 74**

## ELECTRODE CONTROL SYSTEMS FOR INERT ATMOSPHERE AND VACUUM FURNACES

**E. J. Borreback**

There are various types of regulators applicable to consumable or nonconsumable electrode control for inert atmosphere and vacuum melting furnaces. These types will differ mainly in the particular device employed to detect and relay the proper control message from the arc to the electrode positioning device. This paper discusses the operating characteristics and relative merits of various regulator types, listing them as mechanical, electromechanical, and electrical regulators. There is also some discussion regarding the ability of the regulator to overcome certain arc stabilizing deficiencies of the power supply.

**Abstract No. 75**

### THE HIGH INTENSITY ARC: ELECTRODE REQUIREMENTS FOR METALLURGICAL APPLICATIONS

**Samuel Korman and Charles Sheer**

Vapor phase reactions by the high intensity arc involve rigid specifications for electrodes which comprise mixtures of carbon and nonconducting ore. Economic and reaction considerations on one hand and electrical requirements on the other impose conflicting specifications with regard to ore-carbon ratio. Vaporization rates vary linearly with current density, the slopes depending on latent and specific heats of particular components. Proper balance of factors is therefore essential to maximize erosion efficiency and yield.

## ELECTROTHERMICS AND METALLURGY—MARGINAL ORES

**Abstract No. 76**

### A NEW CONCEPT OF TREATING HIGH IRON BAUXITES IN THE ELECTRIC FURNACE

**M. J. Udy**

High iron bauxites and "red mud" wastes from the Bayer process are smelted without lime or basic fluxing material. Iron is reduced and removed as a very low titanium iron and the alumina and titanium oxide upgraded in a slag composed chiefly of $Al_2O_3$, $SiO_2$, and $TiO_2$. The slag is decomposable by sulfuric acid for the recovery of $Al_2(SO_4)_3$ and $Ti_2(SO_4)_3$ or as $Al_2O_3$ and $TiO_2$. The acid is recovered for re-use. Acid consumption is low because acid constituents of the slag are minor.

**Abstract No. 77**

## UTILIZATION OF SILICEOUS MANGANESE ORES FOR PRODUCTION OF SILICOMANGANESE

**W. E. Anable**

Beneficiation and smelting studies by the Bureau of Mines have demonstrated effective methods for utilizing siliceous ores for the manufacture of silicomanganese. In pilot plant beneficiation test work, a high percentage of the manganese was recovered in the flotation concentrate that contained from 32 to 38% Mn and about 30% $SiO_2$ plus $Al_2O_3$. Reduction of the concentrate and off-grade manganese ores of comparable composition in the continuous electric smelting furnace resulted in the production of commercial silicomanganese.

**Abstract No. 78**

## THE USE OF WASTE CARBONACEOUS MATERIALS IN ELECTRIC SMELTING

**R. R. Rogers and G. E. Viens**

Use of wood chips, bark, and other waste carbonaceous materials has been investigated in smelting experiments performed in a 250 kva arc furnace. The advantages and disadvantages of using such materials are outlined, particular attention being paid to results obtained in smelting a manganese ore. The importance of fixed carbon determinations is emphasized, and a new method for making such determinations is described. Data on the fixed carbon content and the bulk density of various waste carbonaceous materials are presented.

**Abstract No. 79**

## ALASKA'S POWER RESOURCES IN RELATION TO MINERAL DEVELOPMENT

**Ivan Bloch**

A large number of potential Alaskan hydropower sites appear feasible of development. Some of them are favorably situated to facilitate the utilization of the Territory's mineral resources such as iron, copper, nickel, chromites, and possibly others. With decreasing availability of abundant, low-cost supplies of hydroelectricity in the 48 States, Alaska's power potential warrants immediate consideration, especially in the southeastern and central portions accessible to tidewater for electroprocess industry establishment.

**Abstract No. 80**

## PRODUCTION OF THORIUM

**T. C. Runion and F. L. Cuthbert**

The role of thorium as a marginal raw material in our national economy is discussed briefly and the rudiments of the thorium production process are presented as developed by Iowa State College and as modified and improved by the National Lead Co. Reference is made to a wet process for making thorium tetrafluoride, to the induction melting of thorium in stabilized zirconia crucibles, and to the development of consumable electrode arc melting techniques for the production of high-purity thorium metal.

**Abstract No. 81**

## PROBLEMS IN THE EXTRACTION OF THORIUM AND RARE EARTH FROM ORES

**H. E. Kremers**

Various types of domestic and foreign ores suitable for the production of thorium and rare earth materials are available. Industrial use of each type involves both chemical and economic problems. The relationships of costs of production, relative sizes of the markets

for thorium and for rare earths, and degree of purification required determine the most suitable ore material.

**Abstract No. 82**

## PROCESSING OF ALLUVIAL SANDS FOR THE RECOVERY OF TANTALUM-COLUMBIUM BEARING MINERALS

**J. E. Shelton**

This paper discusses the beneficiation of alluvial sands to concentrate selectively columbium-tantalum bearing minerals and other radioactive minerals as an aid in evaluating deposits and the production of commercial products. It describes the high ratio of concentration achieved by attrition scrubbing, magnetic, electrostatic, gravity, and flotation procedures.

**Abstract No. 83**

## ELECTRODEPOSITION OF MOLYBDENUM

**T. T. Campbell**

A review of the literature on the electrodeposition of molybdenum from aqueous, nonaqueous, and fused salt systems is presented along with a discussion of work performed at the Albany Station of the U. S. Bureau of Mines.

This research was devoted principally toward attempts to electrodeposit molybdenum from nonaqueous media such as liquid ammonia, formamide, acetamide, hydrazine, and other organic solvents. While thin plates of pure molybdenum and various deposits of molybdenum alloys were obtained, the procurement of massive deposits of pure metal was not realized. In general, the work was confined to the halides of molybdenum and includes a discussion of the preparative techniques used in forming and handling the halides.

## ELECTROTHERMICS AND METALLURGY—PYRO-METALLURGICAL REFINING

**Abstract No. 84**

### SEPARATION OF PLUTONIUM FROM URANIUM BY DISTILLATION, MAGNESIUM EXTRACTION, AND SALT EXTRACTION

**R. A. Barney, A. G. Buyers, D. Cubicciotti, F. J. Keneshea, A. Saul, and S. J. Yosim**

Experiments are reported in which plutonium is separated from uranium by pyrochemical processes. The methods described are: distillation, liquid metal extraction, and fused salt scrubbing. Scrubbing with molten $UF_4$ or a mixture of fluorides is very effective in removing Pu from uranium, while in the distillation method, the rate of evaporation of plutonium from uranium follows Raoult's law. Magnesium has been found to extract plutonium from uranium to a varying degree depending on the impurities present.

**Abstract No. 85**

### PRECIPITATION PROCESSES FOR LIQUID METAL FUELS AND BREEDERS

**R. J. Teitel**

Uranium and thorium are very insoluble in liquid lead, bismuth, and tin at low temperatures. Consequently, practically all of the uranium or thorium in fuels and breeder systems, respectively, can be removed by precipitation of intermetallic compounds. The radiation products remain essentially in the liquid phase and can be removed by purifying the liquid phase after filtration or other phase separation processes. Data for this type of process are presented to illustrate the method along

with flow sheets and some proposed physical arrangements.

**Abstract No. 86**

## MELT REFINING OF URANIUM METAL

**H. M. Feder, L. Burris, and N. Chellew**

Minimum requirements for a method of recycling the fuel from a fast nuclear power reactor are: (*a*) repair of radiation-induced damage; (*b*) removal of deleterious fission products; and (*c*) conservation of bred plutonium. Data will be presented to show that melting and liquation of uranium in refractory oxide crucibles brings about the required purification by volatilization and preferential oxidation. The influence of operating conditions on the degree of refinement and on the recovery of uranium and plutonium will be discussed.

**Abstract No. 87**

## URANIUM HEXAFLUORIDE DISTILLATION

**R. K. Steunenberg**

Various processing schemes have been proposed in which spent uranium fuels are dissolved in a liquid fluorinating agent such as bromine trifluoride. The uranium is recovered as the hexafluoride, which is purified and decontaminated from radioactive fission products by distillation. This concept has been extended to fuels such as zirconium and aluminum alloys, which are not attacked by bromine trifluoride. The fuel is dissolved by hydrofluorination in a high temperature fused fluoride medium, followed by volatilization of the uranium with gaseous fluorine or halogen fluorides. The radioactive fission product wastes are handled as small volumes of the solidified melt.

**Abstract No. 88**

## URANIUM PURIFICATION BY ELECTROREFINING

**L. W. Niedrach and A. C. Glamm***

The feasibility of a high temperature electrorefining process for the decontamination of uranium from associated fission products has been demonstrated. Use has been made of the low-melting alloys of uranium with nickel to obtain molten products at temperatures below the melting point of pure uranium. Decontamination factors of between 80 and 500 have been obtained for representative fission products. The effects of temperature, current, and salt-bath composition on cell efficiency and cell operation are discussed.

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* Knolls Atomic Power Lab., operated by the U. S. Atomic Energy Commission by the General Electric Co.

**Abstract No. 89**

## LIQUID METAL EXTRACTION OF REACTOR FUELS

**A. F. Voigt, F. H. Spedding, A. H. Daane, and others**

A number of metals, notably silver, rare earths, and alkaline earths, are immiscible with uranium in the molten state. Experiments have been conducted on the extraction of uranium, containing fission products, and plutonium, with silver and several rare earths. By a combination of volatilization and extraction, removal of plutonium and many of the fission products is obtained. The application of this technique to a simple decontamination and refabrication cycle for fuel elements will be discussed.

## ELECTROTHERMICS AND METALLURGY—RARE EARTHS

**Abstract No. 90**

### METALLURGY AND PHYSICAL PROPERTIES OF RARE EARTH METALS

**F. H. Spedding**

All of the pure rare earth metals have now been produced in appreciable quantities and the author will discuss the methods used to produce pure rare earth metals at Iowa State College, and the physical properties of these metals insofar as they have been measured.

**Abstract No. 91**

### FLAME SPECTRA OF SOME RARE EARTHS

**A. W. Berger and T. F. Powers**

Flame spectra of some rare earths are presented. Quantitative analysis for scandium, yttrium, lanthanum, and lutetium in simple rare earth mixtures is rapid. Interference by rare earths of neighboring atomic numbers is considered and calibration curves given. The spectra were obtained in the hydrogen-oxygen flame using the Beckman DU spectrophotometer with flame- and energy-recording attachments.

**Abstract No. 92**

### A CAUSTIC PROCESS FOR THE TREATMENT OF MONAZITE AND XENOTIME

**Paul Kruesi**

A process for the treatment of monazite, the principal ore of thorium and the rare earths, and xenotime, an ore analogous to monazite but containing principally yttrium group rare earths, is described. The process uses concentrated

caustic soda solution at elevated temperature in primary treatment followed by separation of thorium and rare earths by selective solution with hydrochloric acid. Data relative to operating conditions, yields, and product purities in the industrial application of this process are presented.

**Abstract No. 93**

## EQUILIBRIUM AND KINETIC STUDIES ON THE PRASEODYMIUM OXIDE SYSTEM

**C. L. Sieglaff and L. Eyring**

Equilibrium dissociation pressure studies, gravimetric analyses, and x-ray diffraction studies have been carried out on praseodymium oxides in the oxygen pressure range of 1–10 atm and a temperature interval of 200°–400°C. A phase diagram for the praseodymium oxide system is proposed for the several compounds, many nonstoichiometric, in the composition range $PrO_{1.8}$ to $PrO_2$. Kinetic studies have been carried out on the high pressure oxidation of $PrO_{1.833}$ to $PrO_2$.

**Abstract No. 94**

## STUDIES ON COMPLEX FORMATION IN LANTHANON ALIPHATIC CARBOXYLATES

**R. C. Vickery**

The formation of complexes between the lanthanons and aliphatic carboxylic acids has been studied by various techniques. Stability constants have been derived for some of the complexes studied and these are seen to vary through homologous series according to the number of carboxyl ligands in the molecule. The presence of amino groups in the ligand molecule enhances complex stability. Correlation of absorption spectra with stability series and other data has

been attempted and some degree of association has been found.

## ELECTROTHERMICS AND METALLURGY—SUPER-REFRACTORIES

**Abstract No. 95**

### HIGH TEMPERATURE MATERIAL REQUIREMENTS IN THE AIR FORCE

**R. A. Jones**

A general discussion will be presented of the problems presented by high temperatures in aircraft and aeronautical equipment. Complications resulting from aerodynamic heating will be discussed with emphasis on the role of heat resistant materials in surmounting these problems.

**Abstract No. 96**

### RECENT NAVY EVALUATIONS OF CERAMIC AND CERMET MATERIALS

**H. Hessing, J. J. Harwood, and J. F. Erthal**

Recent naval activity in high temperature and stress resistant cermets and ceramics is briefly described. Navy Laboratory cross-bending (modulus of rupture), thermal-shock and creep-rupture tests on metal impregnated SiC and on hot pressed $MoB_2$, $TiB_2$, TiC. $MoSi_2$, $B_4C$ and some combinations of these are reported. Hot spin evaluations of small integrally bladed cermet turbine wheels and industry development work for the Navy on boride cermets are also described. Tentative conclusions are indicated.

**Abstract No. 97**

### DEFECT STRUCTURE AND THE TEMPERATURE DEPENDENCE

OF STRENGTH OF AN INTERMETALLIC COMPOUND

**J. H. Westbrook**

The temperature dependence of hardness of the intermetallic compound AgMg was studied over the entire homogeneity range. The effect of defect structure on hardness at high homologous temperatures differs radically from that at low temperatures. These results, over virtually the full homologous temperature range, appear to rationalize previously contradictory studies of the effect of defect structure on the room temperature strength of intermetallic compounds.

**Abstract No. 98**

## THE ELASTIC PROPERTIES OF SUPER-REFRACTORY MATERIALS BY A SONIC METHOD

**S. M. Lang**

In order to provide some of the engineering data necessary for the efficient use of various refractory oxides, carbides, borides, cermets, and intermetallics, their elastic constants—Young's modulus, shear modulus, Poisson's ratio, and bulk modulus—have been determined at room temperature. Some data on the variation of these constants with temperature and oxidation have been obtained. Also, a statistical evaluation was used to correlate fabrication techniques and property values.

**Abstract No. 99**

## KT SILICON CARBIDE

### A New High-Density Silicon Carbide Body

**K. M. Taylor**

This paper describes a new, self-bonded silicon-carbide body having an average bulk density of about 95% of theoretical. Maximum impurities are

approximately 5%. Strength at temperatures above 1400°C are much higher than for other silicon-carbide ware, except the hot-pressed form, which it resembles in structure. Other outstanding properties include impermeability, unusually high thermal conductivity, and excellent resistance to oxidation, erosion, and many corrosive materials. Unlike hot-pressed silicon carbide, it is readily fabricated into intricate shapes.

**Abstract No. 100**

## INFILTRATED TITANIUM CARBIDE

### An Improved Cermet for Turbine Bladings

**C. G. Goetzel**

Cermet-type materials based on titanium carbide suggest themselves for turbine bladings and nozzles because of their attractive stress rupture properties and lighter weight than that of conventional alloys. However, one of the major shortcomings of metal-bonded titanium carbide is its brittleness, inherent in all ceramics and cermets. The infiltration technique provides titanium carbide cermets with higher impact resistance and stress rupture properties than those of present blading alloys. Further, composite structures are produced containing binder alloy-rich leading and trailing edges and high-alloy root sections.

**Abstract No. 101**

## THE EFFECT OF PARTICLE SIZE ON THE BULK DENSITY AND STRENGTH PROPERTIES OF URANIUM DIOXIDE SPECIMENS

**M. D. Burdick and H. S. Parker**

Fused uranium dioxide was separated into fractions of varying particle size by air separation. Specimens of the

nominal size of ⅛ in. by ¼ in. by 1½ in. were formed by hydrostatic pressing, firing, and lapping. The interrelations between original particle size, flexural strength at several test temperatures, and bulk density are shown. Recrystallization of the urania fragments occurred during the firing treatment.

**Abstract No. 102**

## SOME PHYSICAL PROPERTIES OF HIGH-DENSITY THORIUM DIOXIDE

**S. M. Lang and F. P. Knudsen**

A number of strength properties and the elastic constants of a very high density form of thorium dioxide were determined at both room temperature and at 1000°C. All of the test specimens attained at least 99% of theoretical density; all were extremely brittle. They were fabricated from a mixture of 99½% of low-calcined $ThO_2$ and ½% of CaO (by wt), hydrostatically pressed at 30,000 psi, and heated for 1 hr at 1800°C.

**Abstract No. 103**

## "ROCKIDE" COATINGS FOR JET NOZZLES

**W. L. Howe**

(No abstract received)

**Abstract No. 104**

## THE STATUS OF CARBIDES, BORIDES, CERMETS, AND INTERMETALLICS FOR HIGH TEMPERATURE SERVICE

**M. F. Judkins**

The need for a versatile high temperature material is evident—the problem is being attacked vigorously, but the solution is still in the future. Scant hope exists of finding a metal or developing a metallic alloy, if we discount the pos-

sibility of adequately protecting molybdenum. Carbides, borides, cermets, and intermetallics exhibit the greatest potential but their shortcomings compel serious design and service compromises. This presentation endeavors to interpret chemical, physical, and mechanical properties of existing material and to describe their fields of usefulness.

**Abstract No. 105**

## USE OF CERMETS AS TURBINE BLADES

**G. C. Deutsch**

An investigation to determine the feasibility of utilizing cermets for turbine blading will be reviewed. Cermet blades were operated in a full-scale turbo-jet engine. It was found that problems arose in the mechanical blade fastening device, inspection for blade uniformity, and impact. Through design improvements in the fastening device and through improved inspections, lives in excess of 240 hr and greater reliability were achieved. Susceptibility to impact remains as an important problem area.

**Abstract No. 106**

## USE OF SUPER-REFRACTORIES IN ROCKET THRUST CHAMBERS

**W. R. Sheridan**

The present paper deals with the use of super-refractories in rocket thrust chambers burning liquid propellants. The properties of an ideal refractory for this application are outlined, and results of tests on actual refractories are given. Materials included are silicon carbide, graphite, zirconia, zirconium boride, boron nitride, and several others. Finally, the field of potential application is suggested in terms of chamber size, duration of firing, and quantity to be produced.

## INDUSTRIAL ELECTROLYTIC

**Abstract No. 107**

### A COMMERCIAL PROCESS FOR ELECTROWINNING MANGANESE

**M. C. Carosella and R. M. Fowler**

A review of the development of a novel process for the electrowinning of manganese from aqueous solution is presented with emphasis on the raw materials used and the advantages gained thereby. As a result of the development of this process a commercial plant was built. A description of the method of quality control and chemical analyses and characteristics of the metal produced in the plant at Marietta, Ohio, is also given.

**Abstract No. 108**

### CURRENT EFFICIENCY OF ANODIC OXIDE COATING FORMATION ON COMMERCIAL ALUMINUM ALLOYS

**G. H. Kissin and R. V. Paulson**

The current efficiency of anodic oxide formation in sulfuric acid of a number of commercially important aluminum alloys was studied. All alloys were anodized at a constant current density of 12 amp/ft$^2$ in 15% sulfuric acid at 25°C. Some exceptions were noted to the general rule that current efficiency varies inversely as alloy base purity. Contrary to previous reports in the literature, it was found that the anodic coating thickness obtained in a given anodizing time was independent of the alloy. Cell voltages observed in anodizing at constant current density bear no simple relationship to alloy composition. The behavior of several alloying constituents during anodizing was observed and an attempt is made to correlate this behavior with current efficiency and voltage data.

**Abstract No. 109**

## THE STRUCTURE OF KANIGEN*

**A. W. Goldenstein, G. Gutzeit,† W. Rostocker, and F. Schossberger**

An analysis has been made of the structure of nickel deposit produced by the catalytic nickel generator process. X-ray and electron diffraction reveal that Kanigen is an amorphous solid. The structure appears to be unrelated to and independent of the nature of the substrate and of the thickness of the deposit.

Metallographic examination reveals a dense material free from voids and unusually perfect conformity to the substrate surface profile. Etching produced a lamellar structure. In platings the lamellae lie parallel to the plane of the substrate. Growth faults can be observed traversing the thickness dimension from substrate surface irregularities.

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* Trade name for the deposition product of a catalytic nickel generator.

† Present address: Associate Director of Research, General American Transport Corp., Chicago, Ill.

**Abstract No. 110**

## STUDIES OF A VERTICAL ROTARY MERCURY CATHODE CELL

**Shinzo Okada and Shiro Yoshizawa**

Fundamental research and industrial tests on a vertical rotary mercury cathode cell in Japan will be reported, including studies of the mercury film formed on the rotary disk, characteristics of a small pilot cell, and then of an industrial-size unit. The latter was found to operate at a current efficiency and terminal voltage equivalent to the horizontal cell with the advantages of a smaller floor space and a higher purity of chlorine.

**Abstract No. 111**

## ELECTROLYTIC PRODUCTION OF BROMATES

**Takashi Osuga and Kiichiro Sugino**

An electrolytic process for the production of potassium or sodium bromate using a pure lead peroxide anode has been operated successfully at Tokyo, by Sanwa Pure Chemicals Co. In this process, a concentrated bromate solution was electrolyzed continuously at a cathode of stainless steel at an anodic current density of 25 amp/dm² at 70°C; current efficiency—about 90%; anode consumption about 50–60 mg/K.amp hr. Pure crystalline bromate could be obtained by cooling the cell effluent at room temperature.

**Abstract No. 112**

(Scheduled paper withdrawn by author)

**Abstract No. 113**

## POLARIZATION IN AN ALUMINUM REDUCTION CELL

**W. E. Haupin**

A method, combining the technique of current reversal with the use of an a-c bridge, is presented for determining electrolytic polarization in an aluminum reduction cell. Polarization was found to be composed of one part with a short time constant and another with a long time constant. Low anode baking temperatures, agitation, high alumina concentrations, or high $NaF/AlF_3$ ratios in the bath decreased polarization. Additions of $MgF_2$, $CaF_2$, or $SrF_2$ had no noticeable effect.

**Abstract No. 114**

## RELATION OF CURRENT EFFICIENCY TO GAS COMPOSITION IN ALUMINUM REDUCTION CELLS

**T. R. Beck**

Data are presented to show that there are significant deviations from the Pearson and Waddington equation, per cent current efficiency = $50 + \frac{1}{2}(\%\ CO_2)$. The deviations are explained by formation of less than 100% $CO_2$ in the initial anode gas and/or secondary reaction of $CO_2$ with carbon and loss of equivalent aluminum without reacting with $CO_2$. An equation is derived for correlating the data and the parameters are discussed.

**Abstract No. 115**

## ELECTROLYTIC PREPARATION OF THORIUM-BISMUTHIDE DISPERSIONS IN BISMUTH FOR BLANKET PREPARATION IN THE LMFR*

**M. A. Steinberg, M. E. Sibert, and R. J. Teitel**

In a liquid metal fuel reactor using thorium as the fuel material, such as the one under investigation at the Brookhaven National Laboratory, thorium is present in the form of $Th_3Bi_5$ dispersed in liquid bismuth. This thorium-bismuthide dispersion in liquid bismuth must be of such size and shape as to facilitate the pumping of the slurry in and out of the reactor for processing and through a heat exchanger for the extraction of heat for power.

Two methods of preparation have been investigated: electrolysis of $ThCl_4$ in alkali metal chloride melts using a liquid bismuth cathode and a similar method whereby fine crystalline thorium is first deposited on a solid cathode and then stirred into a bismuth pool beneath the salt bath. Dispersions of up to 25% Th

* This work was carried out for the Brookhaven National Laboratory, Associated Universities, Inc., Upton, N. Y., under Subcontract No. S-265, Contract AT-30-2-GEN-16-1.

have been prepared in the form of small (20–40 $\mu$) equiaxed particles of $Th_3Bi_5$.

**Abstract No. 116**

## EVALUATION OF ELECTROLYTIC PARAMETERS IN THE PREPARATION OF THORIUM METAL BY FUSED SALT ELECTROLYSIS*

**J. C. Bleiweiss, B. C. Raynes, and M. A. Steinberg**

The preparation of thorium metal by the fused salt electrolysis of thorium chloride in molten sodium chloride under an inert atmosphere has been in part previously reported. The work now described entails an investigation of certain variables in the preparation of thorium metal by the electrolysis of thorium chloride in fused sodium and potassium chlorides. The parameters studied were the ratio of NaCl/KCl, the thorium ion content, the current density, and the electrolysis temperature. The effects of these variables on both the current efficiency and the physical characteristics of the cathode deposits obtained were ascertained. These parameters were substantiated in the scaling up of the process from a laboratory effort to a tenfold increase in operations.

* This work was carried out for the U. S. Atomic Energy Commission, Washington, D. C., under Contract AT-(30-1)-1335.

**Abstract No. 117**

## THE MOBILITY OF THE IONS IN SILVER NITRATE-ALKALI NITRATE MIXTURES

**F. R. Duke, Nobel Ida, and Boone Owens**

The transport numbers of the ions in the pure salts, $NaNO_3$, $KNO_3$, $LiNO_3$, and $AgNO_3$, have been determined. In addition, the transport numbers in the three binary mixtures, $AgNO_3$-alkali

nitrate, have been measured. The cations in each case carry the major portion of the current. The mobility of ions in these mixtures increases with decreasing concentration; that is, the minor constituent cation at each end of the composition scale has unusually high mobility. This phenomenon is discussed in terms of fused salt structure.

**Abstract No. 118**

## THE MECHANISM OF TITANIUM PRODUCTION BY ELECTROLYSIS OF FUSED HALIDE BATHS CONTAINING TITANIUM SALTS

**J. G. Wurm, Lucien Gravel, and R. J. A. Potvin**

Titanium was produced by electrolyzing a molten bath of a sodium and potassium chloride mixture containing potassium fluotitanate $TiF_6K_2$. The formation of trivalent titanium double fluorides of sodium and potassium always preceded the production of metallic titanium during the electrolysis. These new trivalent titanium compounds were positively identified as $TiF_3$,3KF and $TiF_3$,3NaF.

Definite proof was brought forward that during the electrolysis sodium is a primary product and that the mechanism involved in the production of titanium metal proceeds by secondary reactions in two steps: in the first step, the tetravalent titanium is reduced to the trivalent state; in the second step, the trivalent titanium is finally reduced to metallic titanium.

**Abstract No. 119**

## THE ELECTROREFINING OF TITANIUM IN FUSED SALT MEDIA

**D. H. Baker, Jr., and J. R. Nettle**

A short review will be offered of the development of cells, the electrolyte, and

factors pertaining to the recovery of high purity titanium by electrorefining of off-grade sponge and mill scrap. A description, with lantern slide sketches, of one prototype cell which has been developed will be given with a discussion of its operation and the actual mill cost for the electrorefining of scrap sponge.

**Abstract No. 120**

## THE MECHANISM OF DEPOSITION OF TITANIUM COATINGS FROM FUSED SALT BATHS

**M. E. Straumanis, S. T. Shih, and A. W. Schlechten**

The mechanism of the titanizing process consists mainly (~96%) in the direct collision of titanium particles dispersed in a molten salt bath (KCl, NaCl, or mixtures) with the surface of submerged metallic or ceramic objects such as Si, Fe, steel, Cu, Ni, Co, Au, Pt, porcelain or "Alundum". The Ti particles stick to the surface and, if the temperature is high enough (for Fe above 910°C), the Ti diffuses into the substrate forming a diffusion layer, the thickness of which, depending on temperature and time, conforms with the diffusion equation of Rhines. Up to 4% of the coating may be produced by this mechanism. Coatings by this mechanism can also be obtained on Fe in baths of fused salts (KCl or NaCl) containing lower titanium chlorides rather than dispersed metallic titanium with the latter produced by the reaction

$2TiCl_3 + 3Fe = 3FeCl_2 + 2Ti$ or by the $TiCl_3$ disproportionation in reaction.

**Abstract No. 121**

## DEPOSITION OF TITANIUM FROM TITANIUM-OXYGEN ALLOYS ON COPPER, IRON, AND MILD STEEL

**S. T. Shih, M. E. Straumanis, and**

**A. W. Schlechten**

The presence of some oxygen was found to be beneficial in coating titanium on other metals in a fused alkali chloride bath. An improved method of titanizing was developed by controlling the amount of oxygen by the use of prepared titanium-oxygen alloys or of titanium fines of known oxygen content as a source of titanium. The coating occurred in helium for several hours at about 850°C in the case of copper objects, and 1000°C for those of iron and mild steel. The samples, even of intricate shape, were well coated on all sides. The coatings adhered well to the base metals and protected them from corrosion.

## THEORETICAL ELECTROCHEMISTRY

**Abstract No. 122**

### A STUDY OF THE CATHODIC REDUCTION OF OXIDE FILMS ON IRON

II. The Reduction of Magnetite

**H. G. Oswin**

The reduction of magnetite films on iron has been observed under anacrobic conditions. The effects of current density and various electrolytes are presented and discussed.

**Abstract No. 123**

### MECHANISMS OF HYDROGEN PRODUCING REACTIONS ON PALLADIUM

II. Diffusion of Electrolytic Hydrogen through Palladium

**Sigmund Schuldiner and J. P. Hoare**

The rate of diffusion of hydrogen through several thicknesses of palladium for varying current densities was measured. The relationship between the

diffusion current and the total polarizing current was established. The diffusion constant was calculated.

**Abstract No. 124**

## MECHANISMS OF HYDROGEN PRODUCING REACTIONS ON PALLADIUM

### III. Hydrogen Overvoltage on the Polarization and Diffusion Sides of a Cathode-Diaphragm

**J. P. Hoare and Sigmund Schuldiner**

Overvoltage-log current density relationships on both the polarization and diffusion sides of palladium cathode-diaphragms were measured. Effects of diaphragm thickness, cold working, and poisons were determined. It was shown that on the diffusion side, $\eta_d$ is a concentration overvoltage and the rate of the hydrogen producing mechanism is diffusion-controlled.

**Abstract No. 125**

## MECHANISMS OF HYDROGEN PRODUCING REACTIONS ON PALLADIUM

### IV. Potential of the Alpha-Palladium/Hydrogen Electrode

**Sigmund Schuldiner and J. P. Hoare**

In sulfuric acid solution it was shown that the equilibrium potential of an $\alpha$-Pd/$H_2$ electrode against a Pt/$H_2$ electrode in the same solution was 50 mv positive. Although $\beta$-Pd is stable with respect to the alpha phase in the absence of solution, the reverse is true when the electrode is in contact with solution. A mechanism for the phase transition is proposed.

**Abstract No. 126**

## COMPARISON OF THE VARIATIONS OF THE DIRECT METHOD OF MEASURING POLARIZATION

I. Potentiometric Study with Copper Electrodes in Acid Copper Sulfate Solution

**A. L. Ferguson, L. O. Case, and R. S. Karpiuk**

Three variations of the direct method were studied in detail depending on the position of the Luggin capillary tip of the reference half-cell: (*a*) the "front" method, (*b*) "back" method, and (*c*) the "hole" method. Because of the shape of the cell adopted, it was also convenient to compare the Haring method with the others. In this potentiometric study it was found that: (*a*) a uniform current density was absolutely necessary for significant results by any method of measuring polarization; (*b*) the back of the electrode must be insulated to limit the apparent surface area to the cross-sectional area of the cell; and (*c*) the corrections applied for the *IR* drop present in the front method are highly uncertain.

**Abstract No. 127**

COMPARISON OF THE VARIATIONS OF THE DIRECT METHOD OF MEASURING POLARIZATION

II. Oscillographic Study with Copper Electrodes in Acid Copper Sulfate Solution

**A. L. Ferguson, L. O. Case, and R. S. Karpiuk**

To determine whether the differences in polarization values obtained in the potentiometric study of the three variations of the direct method for measuring polarization were due to an active polarization, to an included *IR* drop, or to a combination of these components, the natural decay curves of the depolarization processes were studied with the aid of a cathode ray oscilloscope and auxiliary electronic apparatus. It was possible to identify and determine with

a high degree of accuracy any *IR* drop present in the decay curves and to draw certain conclusions and recommendations for polarization measurements by the direct method.

**Abstract No. 128**

## HYDROGEN OVERVOLTAGE ON LEAD

**Edward Kure,* Ernest Yeager, and Frank Hovorka**

Hydrogen overvoltage measurements on lead in sulfuric, hydrochloric, and nitric acids indicate Tafel slopes from 0.13 to 0.22, depending on the extent of anion adsorption and impurities. The formation of lead hydride and its subsequent decomposition in solution determine the upper limit for the linear range of the Tafel plots. This upper limit has been extended at least tenfold through the use of a flow system which discards the solution after it passes the cathode. In the presence of oxygen, the cathode potential is depressed to that of the lead-lead salt couple at currents below the limiting current density for the transport of oxygen.

* Electric Storage Battery Co. Fellow.

**Abstract No. 129**

## HYDROGEN OVERVOLTAGE ON NICKEL*

**Richard Jefferys, Ernest Yeager, and Frank Hovorka**

Hydrogen overvoltage measurements have been made on nickel by the interrupter technique in sulfuric and hydrochloric acid solutions as a function of concentration and temperature. For 1*N* sulfuric acid at 25°C, the constants of the Tafel equation are $a = 0.43$, $b = 0.096$; for 1*N* hydrochloric, $a = 0.61$, $b = 0.11$. In both electrolytes, positive

deviations from the Tafel equation occur at $10^{-2}$ amp/cm$^2$. These results are compared with hydrogen overvoltage measurements calculated from polarization data for simultaneous deposition of nickel and hydrogen from $NiCl_2$ and $NiSO_4$ solutions.

* Research partially supported by fellowship to R. Jefferys from Harshaw Chemical Co.

**Abstract No. 130**

## MOLECULAR DESORPTION AS A RATE-DETERMINING STEP FOR HYDROGEN OVERVOLTAGE ON PLATINUM

**Gerald Lozier,* Ernest Yeager, and Frank Hovorka**

The desorption of molecular hydrogen is considered as a possible rate-determining step for hydrogen overvoltage on platinum as opposed to atomic recombination. Evidence including hydrogen overvoltage measurements on various platinum alloys is presented to support molecular desorption as rate-determining. For gold alloys of less than 85% mole fraction gold, the $a$ and $b$ constants of the Tafel equation are substantially the same as for pure platinum, while the limiting current density is approximately proportional to the mole fraction of gold.

* Present address: RCA Laboratories, Princeton, N. J.

**Abstract No. 131**

## NITROGEN OVERPOTENTIAL ON BRIGHT PLATINUM IN LIQUID AMMONIA SOLUTIONS

**Morris Eisenberg**

The polarization of bright platinum electrodes associated with the nitrogen evolution reaction (nitrogen overpotential) was determined in liquid ammonia solutions for the temperature range

−38° to −65°C. Following corrections for concentration polarization, the results were interpreted as chemical polarization in the light of Tafel's equation. Values of the exchange current density, $i_o$, and of the transfer coefficient, $\alpha$, were calculated and the results discussed in relation to the experimental conditions.

**Abstract No. 132**

## HIGH CURRENT ELECTRONIC INTERRUPTER FOR THE STUDY OF ELECTRODE PROCESSES

**W. E. Richeson and Morris Eisenberg**

The design of a current interrupter capable of handling currents up to 5 amp and which can be modified to handle even larger currents is presented. The interrupter is exceptionally versatile, has a fast rise time, a variable conducting level, a switching rate of 500,000 cps to any longer period desired, allows symmetrical or asymmetrical switching, automatic or manual operation, and is capable of presenting a d-c level of current with any desired ripple placed on that level. Included are some experimental results to illustrate its application in studies of electrode polarization. Suggestions on how to avoid difficulties in the use of such a device, and a discussion of its design in relation to other interrupters are given.

**Abstract No. 133**

## DIFFUSION-CONTROLLED METAL DEPOSITION ON STATIONARY MICROELECTRODES

**T. Pavlopoulos and J. D. H. Strickland**

The diffusion currents for the reduction of thallium, silver, lead, and cadmium ions at stationary platinum electrodes are shown not to conform to the

Nernst diffusion equation but to an empirical equation $I_d = K.n.F.D^{0.775} \cdot (C_i - C_e)^{120} \cdot (1/2r + 1/\delta)$, where $I_d$ is the current density, $(C - C_e)$ the concentration gradient at the electrode, $r$ the radius of the electrode, and $\delta$ a transfer layer thickness. These results quantitatively support a treatment based on convective diffusion already suggested by Agar.

**Abstract No. 134**

## PROBLEMS OF ELECTROCHEMICAL NOMENCLATURE AND DEFINITIONS

**Pierre Van Rysselberghe**

The recent work of IUPAC and CITCE Commissions in the field of electrochemical nomenclature and definitions, and the present situation with respect to the following concepts: electromotive force, "electric tension," electrode potential, oxidation potential, reduction potential, redox potential, electrochemical affinity, oxidation affinity per Faraday, reduction affinity per Faraday, etc., are reviewed and discussed.

**Abstract No. 135**

## MATHEMATICAL STUDIES ON GALVANIC CORROSION

### V. Calculation of the Average Value of the Corrosion Current Parameter

**J. T. Waber, John Morrissey, and John Ruth**

Mathematical analysis for mean current density has been completed for one general and two limiting ratios of electrode and corrodent dimensions using the coplanar, juxtaposed arrangement of long, narrow electrodes as in previous papers. The mathematical expressions were reduced to numerical evaluations and the results summarized in perspective illustrations.

The characteristic ratio ($\lambda/\mathfrak{L}$) was used to emphasize the fact that relative and not absolute dimensions of the system establish its behavior. Comparison between theory and two experimental studies shows good agreement.

**Abstract No. 136**

## THE ANODE BEHAVIOR OF GERMANIUM IN AQUEOUS SOLUTIONS

**D. R. Turner**

Anode characteristics of *n*- and *p*-type germanium are different. A large voltage barrier is observed at about 0.8 ma/cm² current density at room temperature on *n*-type, but not on *p*-type electrodes. The barrier on 3 ohm-cm *n*-type germanium anodes breaks down at about 9 v in many electrolytes. During anodic dissolution, the surface appears to be covered with about a monolayer of oxide or hydroxide, suggesting formation of a complex ion with hydroxyl or oxide radicals attached. A mechanism is proposed for the over-all anode dissolution process.

**Abstract No. 137**

## ELECTROKINETIC POTENTIALS ON BULK METALS BY STREAMING CURRENT MEASUREMENTS

### II. Gold, Platinum, and Silver in Dilute Aqueous Electrolytes

**R. M. Hurd and Norman Hackerman**

The electrokinetic ($\zeta$) potentials of platinum, gold, and silver were obtained from streaming current measurements in distilled water. The values were 60.8, 61.0, and 49.0 mv, respectively. The $\zeta$ potentials of these metals were also measured as a function of concentrations of KCl and KOH. Maxima were observed in all cases except that of gold in KCl solutions. These maxima are qualitatively related to the solubilities of the corresponding chlorides and hydroxides.

**Abstract No. 138**

## ELECTROLYTES OF BINARY SOLUTES IN KETONES

**J. E. Lilienfeld, Helen Y. Hsiao, and H. S. Myers***

In systems of a ketone, a phenolic compound, and sodium hydroxide, with conductivity as constant parameter, composition functions are referred to weight ratio of sodium hydroxide to phenolic compound as ordinates, and weight per cent of phenolic compound in ketone as abscissas. At about 30%, a minimum is common to the presented functions. This, and other findings, indicate an elementary functional dependence of conductivity on molecular weights of both organic components.

* Present address: Department of Chemical Engineering, City College, New York, N. Y.

**Abstract No. 139**

## THE ALLOTROPIC MODIFICATIONS OF CALCIUM

**J. F. Smith, O. N. Carlson, and R. W. Vest**

X-ray diffraction patterns on calcium samples show that 99.9+% Ca exists in only two allotropic forms: face-centered cubic to 464°C and body-centered cubic above 464°C. These results differ from the widely accepted structure; handbooks and tables currently list the high temperature allotrope as hexagonal closest-packed. A previously reported intermediate allotrope of complex structure is due to contamination. The temperature dependence of the electrical resistivity of the 99.9+% Ca is linear for both the face-centered cubic and the body-centered cubic allotrope. Calcium was observed to be self-annealing at room temperature.

**Abstract No. 140**

## A PROPOSED MECHANISM FOR THE ELECTROLYTIC CONDUCTANCE OF SODA-SILICA GLASSES

**A. B. Rothman**

The resistivity measurements of one group of experimenters gives the activation energy for the electrolytic conductance of soda-silica glass as a function of soda content. The activation energy was extrapolated to zero soda content from a least-squares fit of an assumed empirical relation. This energy, 31.1 kcal/mole, agrees well with another value, 31.2 kcal/mole, obtained from measurements on fused quartz using electrodes of sodium nitrite. A microscopic model for the mechanism of conductance is proposed and an expression for the activation energy is derived. The value at zero soda content from this relation, 30.7 kcal/mole, agrees well with the two values mentioned above.

**Abstract No. 141**

## ELECTROCHEMICAL PROPERTIES OF A CATION-TRANSFER MEMBRANE

**N. W. Rosenberg, J. H. B. George, and W. D. Potter**

The electrochemical behavior of a cation-transfer membrane with respect to cations of various charge has been investigated. Measurements have been made of capacity, water content, Donnan sorption, conductance, water transfer, and transport numbers. The results suggest that ionic mobilities are lower in the membrane than in free solution and that there is a high degree of association between the cations and the charge centers of the membrane.

**Abstract No. 142**

## ELECTROCHEMISTRY APPLIED TO ELECTROPHYSIOLOGY

**R. H. Beutner**

Electrochemistry knows two types of potential differences: (*a*) those occurring by contact of aqueous solutions, either with metallic electrodes, or with water-immiscible electrolytic conductors (e.g., massive, fused AgCl can replace metallic Ag in Nernst's concentration cell); these p.d.'s, neglected in electrophysiology, are unrelated to ionic mobility; (*b*) "diffusion potentials" occurring between miscible solutions. These depend on ionic mobility. Electrophysiology relies on this type exclusively and uses the unproven hypothesis that ions acquire differential mobility inside membranes.

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FALL MEETING

at the

**STATLER HOTEL**

Cleveland, Ohio

September 30, October 1, 2, 3, and 4, 1956

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Sessions will be scheduled on

**Batteries**

**Corrosion**

**Electrodeposition**

**Electrothermics and Metallurgy**

**Theoretical Electrochemistry** (joint symposium with Electrodeposition)

Abstracts for the Fall Meeting (*not exceeding 75 words in length*) must reach the Secretary's Office, 216 West 102nd Street, New York 25, N. Y. *not later than June 15, 1956* in order to be included in the program.

*Indicate on abstract for which Division's symposium the paper is to be scheduled.*

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